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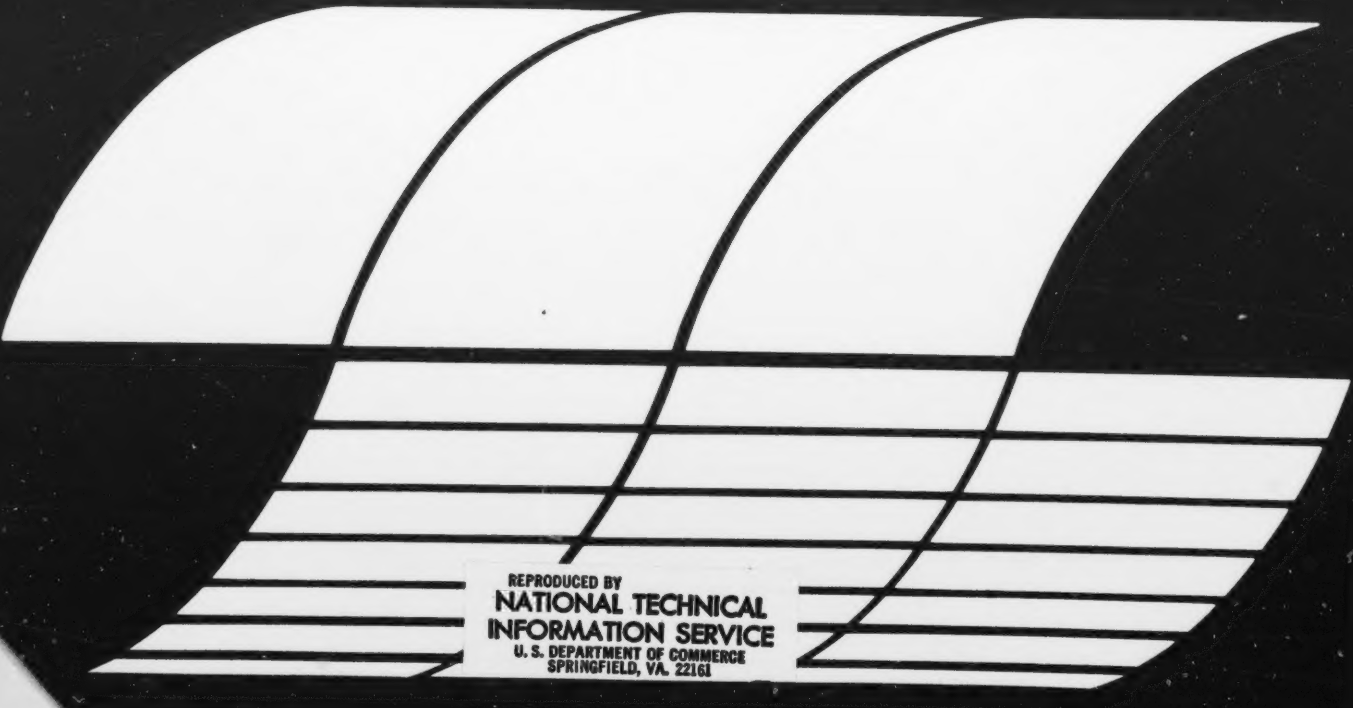

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INVESTIGATION OF PETROLEUM IN THE MARINE ENVIRONS OF THE STRAIT OF JUAN DE FUCA AND NORTHERN PUGET SOUND

Donald W. Brown, Andrew J. Friedman, Douglas G. Burrows,
George R. Snyder, Benjamin G. Patten, Warren E. Ames,
L. Scott Ramos, Patty G. Prohaska, Donald D. Gennero,
D. Douglas Dungan, Marianne Y. Uyeda, and William D. MacLeod, Jr.

NOAA National Analytical Facility
Environmental Conservation Division
Northwest and Alaska Fisheries Center
National Marine Fisheries Service
2725 Montlake Boulevard East
Seattle, Washington 98112

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FOREWORD

Substantially increased petroleum transfer and refining activities are anticipated in the Northern Puget Sound and Strait of Juan de Fuca areas. These activities will increase the chances of chronic and/or acute oil inputs into the marine environment. To provide a basis for measuring future changes in environmental levels of petroleum, a regional study was undertaken. This study was conducted in a region in which only limited amounts of petroleum constituents have been spilled or leaked; however, this region may experience increased petroleum inputs in the future due to the increasing volume of petroleum to be shipped, handled and/or refined. The research was conducted by the Northwest and Alaska Fisheries Center in Seattle. It was a major part of an environmental assessment of the region, supported by the U.S. Environmental Protection Agency and administered by the NOAA Marine Ecosystem Analysis Puget Sound Project.

ABSTRACT

The Northern Puget Sound and Strait of Juan de Fuca regions have accommodated the transportation and refining of petroleum without serious problems from spilled oil. However, proposed activities related to the transport and use of petroleum in these regions increase the chances of significant additions of petroleum to this marine environment. This project was designed to provide an accurate and reliable set of data against which future levels of petroleum compounds can be compared.

This investigation was initiated in February, 1977, to measure existing levels of petroleum in Northern Puget Sound and the Strait of Juan de Fuca, and to investigate spatial and temporal trends in occurrence, concentration, and composition of petroleum-related hydrocarbons. Sediment and/or mussel samples from 23 beaches located strategically along shipping lanes in the Strait of Juan de Fuca, San Juan Islands, and Northern Puget Sound were analyzed for n-alkanes and aromatic hydrocarbons.

All 23 sites were relatively free from petroleum contamination. However, hydrocarbons indicative of petroleum were found at Ediz Hook, March Point, Kydaka Point, Dungeness/Three Crabs, Baadah Point, Sandy Point, Cherry Point, and False Bay. Hydrocarbon concentrations were generally consistent for the quarterly samples from individual sites and also from samples taken at one site every two weeks for three months.

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INTRODUCTION

This investigation was part of a major interdisciplinary study to determine the potential effects of increased petroleum transport and refining activities in the Strait of Juan de Fuca and Northern Puget Sound. The overall study, funded by the Environmental Protection Agency (EPA) and administered by the Marine Ecosystem Analysis (MESA) project, was established to focus the capabilities of NOAA and of Federal, state, and local agencies upon specific environmental problems through intensive research projects. Thus far, MESA has funded more than 20 research investigations designed to help provide a large environmental data base for the region upon which future regulatory, socioeconomic, and resource management decisions may be based (1).

Studies are being conducted to help define the physical and chemical oceanography of the Greater Puget Sound area, the abundance and distribution of the aquatic biota in the area, and the present levels of petroleum hydrocarbons in sediments and aquatic organisms. The establishment of models derived from these studies should help in predicting oil spill trajectories and potential trophic pathways, and in the assessment of environmental impacts of an oil spill if one occurs in these waters.

The Northern Puget Sound and Strait of Juan de Fuca regions have accommodated the transportation and refining of petroleum for years without serious problems from oil spills. However, with the recent increase in tanker transport of crude oil in this region, the risk of a major spill increases. Knowledge of the presence and the distribution of current levels of petroleum is necessary to establish a base to assess future changes and to determine whether petroleum compounds are increasing in this environment.

In 1975, the MESA Puget Sound Project Office held workshops to help identify productive areas of research which could achieve MESA goals, and it invited the Northwest and Alaska Fisheries Center (NWAFC) of the National Marine Fisheries Service (NMFS) to participate. Since the NWAFC had the chemical and biological expertise and the needed facilities, MESA authorized a pilot study during 1976 to study techniques for sample collection and analysis of petroleum hydrocarbons (2). This pilot study established field sampling and laboratory analysis methodologies suitable for investigating baseline levels of hydrocarbons in the intertidal zone.

This investigation is an extension of that pilot study. It was initiated during February, 1977, to measure existing levels of petroleum in Northern Puget Sound and the Strait of Juan de Fuca, and to investigate spatial and temporal trends in occurrence, concentration, and composition of petroleum-related hydrocarbons. The principal objective was to provide an accurate and reliable set of data against which future levels of petroleum compounds can be compared. To this end, sediment and/or mussel samples were collected and analyzed from 23 beaches located strategically along shipping lanes in the Strait of Juan de Fuca, San Juan Islands, and Northern Puget Sound (Fig. 1).

An initial experiment was conducted to establish the variability of hydrocarbon levels among individual sediment samples along a 30-m stretch of

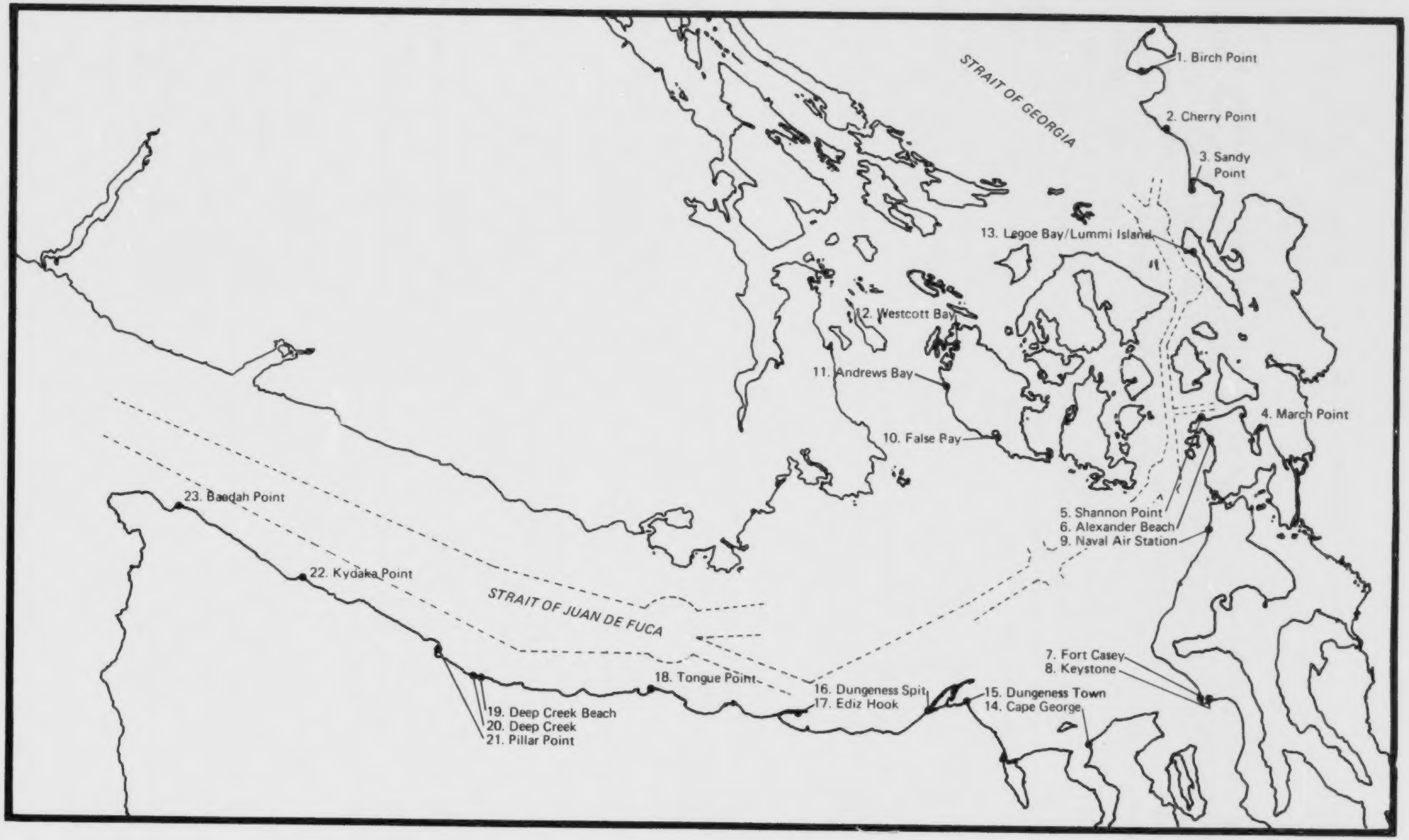
1. Birch Point
2. Cherry Point
3. Sandy Point
STRAIT OF GEORGIA
13. Legoe Bay/Lummi Island
12. Westcott Bay
11. Andrews Bay
10. False Bay
4. March Point
5. Shannon Point
6. Alexander Beach
9. Naval Air Station
7. Fort Casey
8. Keystone
15. Dungeness Town
14. Cape George
16. Dungeness Spit
17. Ediz Hook
18. Tongue Point
STRAIT OF JUAN DE FUCA
19. Deep Creek Beach
20. Deep Creek
21. Pillar Point
22. Kydaka Point
23. Baadah Point

Figure 1. Sampling sites in the Strait of Juan de Fuca and Northern Puget Sound. Dotted lines denote shipping lanes

beach and the variability of hydrocarbon levels in sediment samples relative to tidal height. This initial study, described in the Sampling Design Study, was conducted during March, 1977. The data resulting from this investigation were used to design the quarterly sampling protocol. Quarterly sampling, described in the Hydrocarbon Baseline Study, began in April, 1977, and continued through February, 1978. Other experiments included (a) studies of variability of hydrocarbon levels at a single beach over short periods of time, and (b) comparisons of variabilities in hydrocarbon levels at six beaches. These experiments are described in the Temporal Variability and Beach Variability sections of this report. Preliminary findings have been previously documented in monthly reports to MESA and in oral reports at two meetings of the MESA Puget Sound project. For clarity, the results are described in four separate sections.

Overview

Petroleum and its products enter Northern Puget Sound and the Strait of Juan de Fuca primarily from petroleum transport, petroleum refining operations, shipping, boating, municipal and industrial effluent, and possibly natural seepage. Accidental spillage of crude oil from tanker operations is a potential source of petroleum contamination in these regions (3). If petroleum spillage occurred, the intertidal zone would probably be seriously contaminated because of its constant exposure to surface water. Hydrocarbons are known to accumulate in sediments and may be retained there for periods ranging from months to years (4,5). Mussels are sedentary organisms that may concentrate hydrocarbons from the water column and can also depurate them (6). Therefore, appropriate sampling and analysis of these two substrates should provide information on exposures of the intertidal zone to hydrocarbons.

Detecting and monitoring environmental intrusion by petroleum are complicated by the complex composition of petroleum and by the numerous sources of many hydrocarbons. Petroleum is a complex mixture of thousands of compounds that vary considerably in relative abundances (7,8). The compounds are mainly hydrocarbons that range in size from 1 to more than 70 carbon atoms and may be arranged in classes having similar chemical characteristics. Clark and Brown (7) classified petroleum hydrocarbons according to Table 1. Aliphatic hydrocarbons may be saturated or unsaturated, straight chain, branched chain or cyclic. Aromatic hydrocarbons are highly unsaturated cyclic hydrocarbons that may be of particular significance because of their potential biological effects. In addition, petroleum contains many heteroatomic compounds and metallic constituents.

Many of the hydrocarbons present in the environment also arise from non-petroleum sources, such as biological materials (5,8,9) and products of combustion (10,11,12). However, certain distinguishing characteristics permit partial differentiation between petroleum and non-petroleum hydrocarbons. These consist mainly of differences in the occurrence and relative abundance of specific hydrocarbons and classes of hydrocarbons from a given source. The n-alkanes are quite often the predominant compounds in petroleum. These alkanes usually have a regular odd-even carbon number distribution throughout the molecular weight range (Fig. 2) (i.e., the concentration of adjacent n-alkanes is almost equal). Such a pattern of the n-alkanes indicates a fossil origin of the hydrocarbons (13). The n-alkanes produced by recent biological processes are predominantly odd-carbon numbered (Figure 3) (13,14), as opposed to the regular odd-even distribution of n-alkanes in petroleum (Fig. 2). Additionally, the branched-chain alkanes, pristane and phytane, are both present in petroleum at about the same concentration. Both are also produced by biogenic processes, but some researchers have found that phytane generally is not as abundant as pristane (14); thus high ratios of pristane to phytane abundance may indicate biogenic input.

Table 1. Hydrocarbon classes, types, and structures found in refined petroleum products.

		Molecular Structure	
Class	Type	Arrangement of carbon atoms	Characteristic bonding
Aliphatic	Paraffin (alkanes)	Open chain, straight or branched	Saturated
	Olefins (alkanes)	Open chain straight or branched	Unsaturated
Alicyclic	Cycloparaffins	Closed chain, (cyclic or ring)	Saturated
	Cyclo-olefins	Closed chain, (cyclic or ring)	Unsaturated
Aromatic	(various types)	Closed chain (benzenoid ring)	Unsaturated

Due to the chemical complexity of petroleum, often a limited number of individual compounds common to petroleum are chosen to obtain an indication of the amount of petroleum present. The abundance of pristane, phytane, and the C_{10}-C_{31} n-alkanes are commonly used to indicate the occurrence of petroleum (13). More recently, data on individual aromatic hydrocarbons are also being reported for this purpose (7).

The aromatic hydrocarbons in petroleum are characterized by a high proportion of alkyl substituted homologs compared to their unsubstituted counterpart, e.g., the ratio of the methylphenanthrene peaks to the phenanthrene peak in Figure 4. In non-petroleum sources, such as products of combustion processes, the unsubstituted polynuclear aromatic hydrocarbons of 3 or more rings predominate over their substituted homologs, as in Figure 5 (11,12).

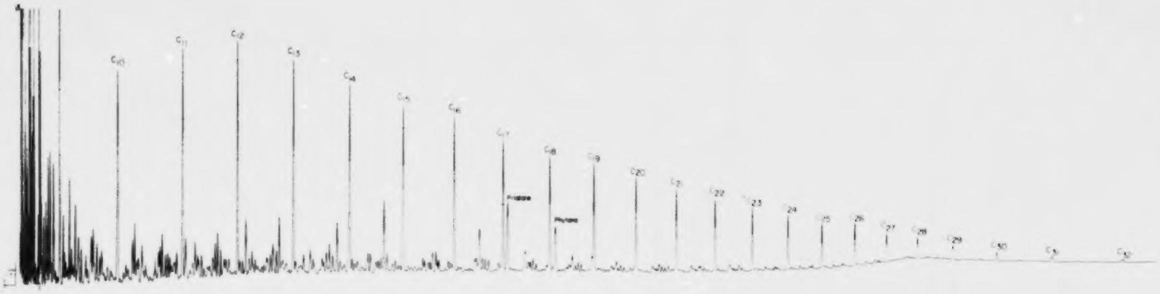

Figure 2. Gas chromatogram of the saturated hydrocarbons from Prudhoe Bay crude oil. C_n denotes n-alkane of given chain length n. Conditions were: 30 m x 0.25 mm WCOT glass column coated with SE-30. 2 μL splitless injection, vaporization at 280°C, split 10:1 after 18 sec with 22 psig helium carrier gas. Column temperature 40° for 5 min, then programmed to 270°C at 4° per min.

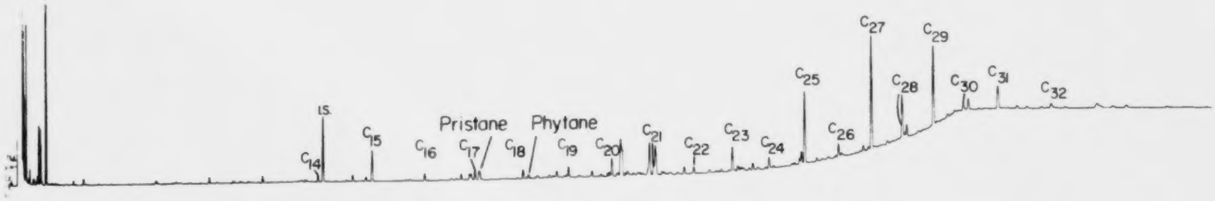

Figure 3. Gas chromatogram of the saturated hydrocarbons from Dungeness/Three Crabs intertidal sediment. C_n denotes n-alkane of chain length n. Conditions same as for figure 2, except column coated with SE 54.

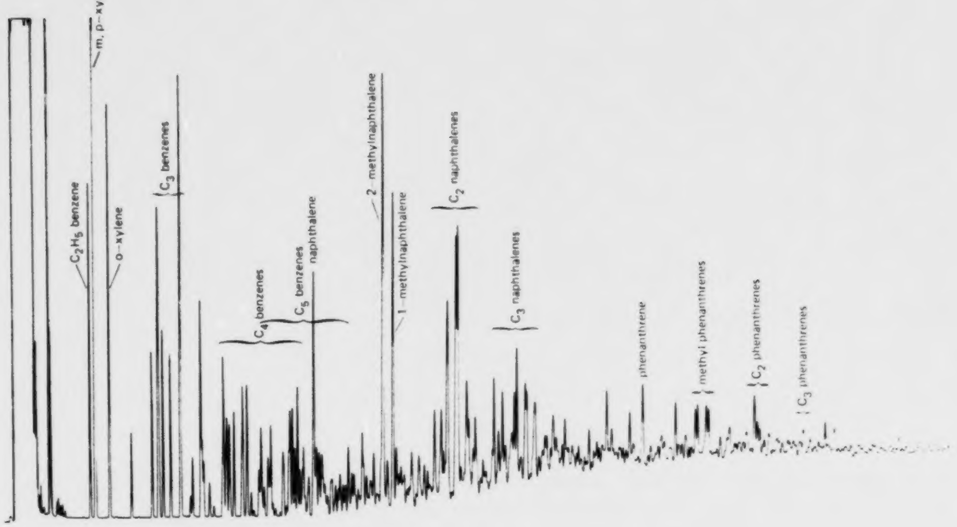

Figure 4. Gas chromatogram of aromatic hydrocarbons from Prudhoe Bay crude oil. Conditions same as for figure 2, except column coated with SE 54.

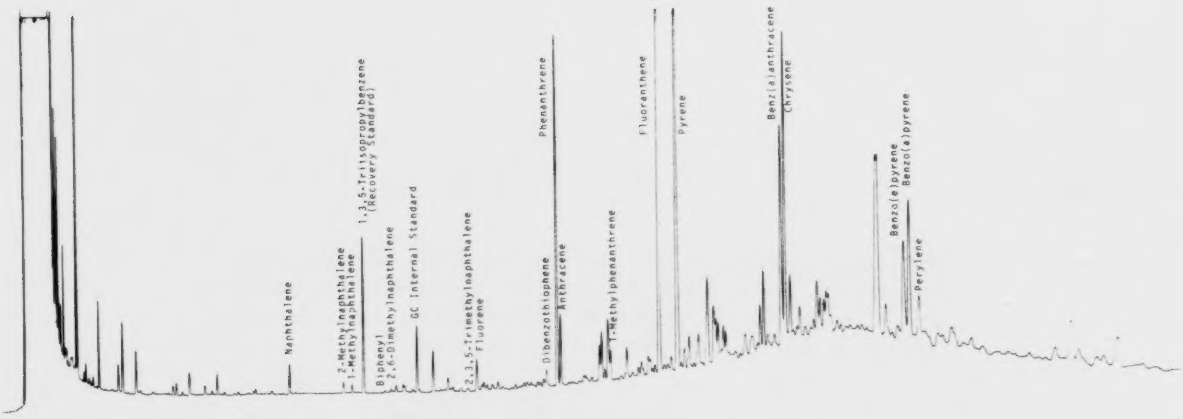

Figure 5. Gas chromatogram of aromatic hydrocarbons from an extract of Duwamish River sediment, Elliott Bay, Seattle, Washington. Conditions same as for figure 2, except column coated with SE 54.

CONCLUSIONS

The Northern Puget Sound Study was conducted to establish the existing degree of petroleum pollution, and to develop data concerning spatial and temporal trends in occurrence, concentration, and composition of petroleum-related hydrocarbons. Petroleum can accumulate in sediments, and components of petroleum in both sediments and the water column can be absorbed and depurated by organisms. The substrates chosen to indicate the present concentration of petroleum hydrocarbons were sediments and mussels. Mussels are sedentary organisms and filter feeders that presumably would reflect the current petroleum hydrocarbon concentrations in their environment.

A Sampling Design Study was conducted to establish the optimum composite sample size, the variability of hydrocarbon levels between samples at a given tidal height, and the variability of hydrocarbon levels in sediment at different tidal heights. To this end ten sediment samples were collected at random points along a 30-m line at tidal heights of 0.6, 0.9, and 1.2 m. Results from this inital study showed that hydrocarbon levels were higher at the 0.6-m height than at either the 0.9- or 1.2-m heights. We also decided that ten 50-g sediment samples collected at random positions along a 30-m length of beach at the 0.6-m tidal elevation could be composited for a sample representative of the beach. We decided that thirty mussels would be collected as close to the sediment sampling area as possible, and a sample of the homogenized composite used for analysis.

The major objective of the Hydrocarbon Baseline Study was to measure concentrations of hydrocarbons present in intertidal sediments and mussels along the Strait of Juan de Fuca and Northern Puget Sound. Samples were collected from 23 beaches adjacent to shipping lanes in the Strait of Juan de Fuca, San Juan Islands, and Northern Puget Sound on a quarterly basis beginning April, 1977, and ending February, 1978.

Results from the analyses showed that the sum of C_{12} to C_{20} *n*-alkane concentrations were generally much higher for the mussels than the corresponding values for the sediments. The average value for mussels was 900 ng/g dry weight compared to 50 ng/g dry weight for sediment. This difference is probably due to biological factors.

The results of the quarterly sampling study showed that all sites were relatively free from petroleum contamination. The average of the sums of the concentrations of C_{12} to C_{20} *n*-alkanes in sediment samples collected quarterly, in order of decreasing values, were: Ediz Hook (150 ng/g); March Point and Kydaka Point (100 ng/g); Dungeness/Three Crabs (86 ng/g); Baadah Point (55 ng/g); Sandy Point (47 ng/g); Cherry Point (33 ng/g); and False Bay (8 ng/g) as compared to the average result of 32 ng/g from the other 11 beaches sampled for sediments. Some of the other 11 beaches showed hydrocarbons that were probably from biological sources which caused their sums to be high. The quarterly averages of the sum of ten selected aromatic hydrocarbons, in decreasing order, were: False Bay (42 ng/g); March Point (39 ng/g); Kydaka Point (29 ng/g) Baadah Point and Sandy Point (19 ng/g); Dungeness/Three Crabs (13 ng/g); Cherry Point (9 ng/g); and Ediz Hook (8 ng/g) as compared to the average result of 3 ng/g for the mussels from the other ten beaches. The hydrocarbons at Ediz Hook, Baadah Point and March Point probably resulted from local industries, municipal input, and/or boating activities. The Dungeness/Three Crabs beach, a site generally considered to be pristine, contained higher concentrations of petroleum-related hydrocarbons than the 14 sites not discussed above. The lowest concentrations were measured at the Naval Air Station site on Whidbey Island.

We conducted a study to determine if there were major short-term changes in hydrocarbon concentrations (Temporal Variability Study). We collected sediment and mussel samples at March Point six times, at approximately two week intervals, beginning September 21, 1977. The results showed the alkane concentrations in sediment were generally consistent over short time periods, e.g., the C_{12} to C_{20} n-alkane sums ranged from 82 to 113 ng/g dry weight (average value 94 ng/g). The values from four quarterly sampling events ranged from 87 to 124 ng/g (average value 100 ng/g). The results for the aromatic compounds were more variable than for the alkanes. The values for a compound generally were consistent for these sampling events, which implies that major changes in concentrations did not occur over short time periods. The results indicate that seasonal mussel variability and short-term variability apparently were not greatly different.

Since the protocol of the baseline study called for an analysis of composited samples from each beach, it was important to determine if the differences in reported hydrocarbon concentrations were due to differences in hydrocarbon levels between sites. To this end we conducted a Beach Variability Study, in which duplicate sediment composites were analyzed from Cherry Point, March Point, Andrews Bay, Dungeness/Three Crabs, Tongue Point, and Baadah Point from the spring and summer quarters. The results for duplicate samples from these six beaches were rather consistent and were similar to those for replicate analyses of single samples. For example, the sum of the concentrations of selected alkanes at March Point averaged 119 ng/g (range 82 to 158). These values were lowest at Tongue Point, having an average value of 19 ng/g (range 14 to 22). Excepting the Andrews Bay spring sample, the average of the sum of the concentrations of selected aromatic hydrocarbons was highest at March Point (63 ng/g, range 26 to 97) and lowest at Tongue Point (2 ng/g,, range 0 to 3), indicating that the differences noted between beaches are real.

RECOMMENDATIONS

Quarterly monitoring should continue a second year but at a reduced level; i.e., only sediment samples should be analyzed from the following sites in Northern Puget Sound and the Strait of Juan de Fuca:

1. Baadah Point
2. Kydaka Point
3. Crescent Bay
4. Ediz Hook
5. Dungeness spit
6. NAS Whidbey Island
7. March Point
8. Andrews Bay
9. Cherry Point
10. Birch Point

Benzo(a)pyrene (BAP), a carcinogen, was found in sediments at March Point (as high as 16 ppb). It should be determined whether the BAP is available to the marine organisms that contact these sediments or whether the BAP is biologically inert because of physical or chemical factors such as binding of the BAP to the sediments.

SAMPLING DESIGN STUDY

The initial study in this project was undertaken in February, 1977, to establish the optimum number of samples needed to prepare a composite sample for sediment analysis, and to determine the variability of hydrocarbon levels in sediments at different tidal heights. March Point was the site chosen for this study because we anticipated that petroleum hydrocarbons would be present due to its proximity to refinery operations. Results from this study were used to design sediment sampling procedures for the remainder of the investigation.

Methods and Materials

Sediment samples were collected at March Point in February, 1977. Three 30-m lines, premarked at 1-m intervals, were placed along the 0.6-, 0.9-, and 1.2-m beach contours. Elevations were gauged from mean lower low water; tidal elevations were calculated from U.S. Department of Commerce tide tables (15). Ten sampling points along each line (total of 30 points) were chosen from tables of random numbers. Duplicate sediment cores (1 for analysis and 1 for reserve) were collected at the selected points (total of 60 samples). Individual prewashed, solvent-rinsed cans served as combination corer-storage containers. Prewashed, solvent-rinsed stainless-steel spatulas were used to keep the sediment core intact and the can full upon withdrawing the sample. Each can of sediment was covered with solvent-rinsed aluminum foil and stored on ice until received in the laboratory, then stored frozen at -20°C until analysis.

The entire sample in each can, about 200 g, was weighed into an extraction bottle to avoid variability due to sub-sampling. The samples were extracted and analyzed using the methods and materials described in Appendix III. The fractions containing the saturated hydrocarbons were analyzed by gas chromatography, and heptadecane was quantitated in each extract. These values were used to estimate the variability of sampling and analysis.

Results and Discussion

The concentration of heptadecane ($\underline{n}$-$C_{17}H_{36}$) appeared to correlate with the concentrations of the other $\underline{n}$-alkanes in these samples; i.e., if the $\underline{n}$-$C_{17}H_{36}$ was high, the other $\underline{n}$-alkanes appeared to be high. Therefore, the $\underline{n}$-$C_{17}H_{36}$ concentration was chosen for quantitation and interpretation. The resulting data are listed in Table 2.

Table 2. Heptadecane n-$C_{17}H_{36}$ in individual sediment samples at three tidal heights at March Point.

Tidal Height	Heptadecane ng/g wet weight	Average
0.6-m	26, 15, 24, 38, 39, 35, 17, 16, 11, 17	24
0.9-m	32, 40, 12, 22, 16, --, 9, 6, 4, 10	17
1.2-m	21, 15, 11, 17, 11, 10, 7, 8, 9, 35	16

The highest average concentration of n-$C_{17}H_{36}$ was found at the 0.6-m tidal elevation. Fine grain sediments which were selected for analysis were most consistently found at the 0.6-m level or lower at the proposed sampling sites.

The results were used to establish the following protocol to obtain sediment samples for the major study:

a. Samples of about 50 g each would be collected along a 30 m length of beach at the 0.6-m tidal elevation.

b. Each sample would be taken with an aluminum or stainless steel corer device 5.5-cm dia. x 2-cm h (47 cm^3).

c. The core would be cut "cookie-cutter" fashion with a steel spatula slipped underneath to lift the core intact. The spatula would be used to scrape excess sediment from the core and the sample would then be placed into a 16-oz sample jar.

d. Ten samples so collected would be combined to form a single composite sediment sample of about 500 g, from which 100 g would be used for hydrocarbon analysis, 20 g for dry weight determination, and 100 g for total organic carbon (TOC) and grain size determination.

HYDROCARBON BASELINE STUDY

The major objective of this investigation was to determine the amounts of hydrocarbons along the Strait of Juan de Fuca and Northern Puget Sound. Twenty-three sites were chosen for sediment and/or mussel collection (Fig. 1). Sediment and mussel samples were collected quarterly in the intertidal zone of beaches adjacent to shipping lanes beginning April, 1977, and ending February, 1978.

Methods and Materials

MacLeod *et al*. (2) reported the methods used during the 1976 pilot study to extract and analyze hydrocarbons from sediments and mussels. We later found that the sediment procedure adopted in that study was less efficient than the exhaustive Soxhlet method (16). We modified the tumbling method to obtain extraction efficiencies comparable to Soxhlet extraction (17). The mussel procedure used was basically the same as described in the pilot study. Both procedures are given in detail in Appendix III.

Many of the sampling sites in the Northern Puget Sound and Strait of Juan de Fuca region were considered to be relatively pristine areas; therefore, the hydrocarbon levels were expected to be low. Consequently, the most sensitive analytical techniques available were needed to measure trace hydrocarbon levels in complex mixtures. Gas chromatography using high-resolution, glass capillary columns provided the desired sensitivity and resolution (2,18). The data from hydrocarbon analyses were reported to Environmental Data and Information Services/National Oceanographic Data Center (EDIS/NODC) on computer paper punch cards (Appendix I).

Site Selection. Criteria for selection of sample sites along the Strait of Juan de Fuca and Northern Puget Sound included: (a) exposure to the oil tanker lanes extending from the entrance of the Strait of Juan de Fuca through the San Juan Islands and north along Northern Puget Sound to the Canadian border; (b) availability of relatively fine grained sediment at the 0.6-m tidal elevation (Sampling Design Study) along a minimum distance of 30 m on a beach; (c) availability of a population of mussels of a length of 3 to 5 cm within the 0.6- to 0.9-m tidal elevation in sufficient quantities for quarterly sampling; and (d) availability of both sediment and mussels within 1 km of each other at each site.

Under these conditions, 23 sampling sites were established (Fig. 1). Mussel and sediment sites were generally less than 0.5 km apart; however, they were separated by 1 km at Deep Creek, by 3 km between Fort Casey (sediment) and Keystone (mussels), by 7 km between Andrews Bay (sediment) and Wescott Bay (mussels), and by 8 km between Cherry Point (sediment) and Lummi Island (mussels).

Letters of intent were sent to owners of industrial and institutional properties in order to gain authorization for access. Private owners were contacted in person and readily agreed to the study.

Sample Collection. The protocol for sediment sampling was developed from the Sampling Design Study. It consisted of placing a 30-m line along the 0.6-m beach contour. The elevation was gauged from mean lower low water and measured using a transit and stadia rod. Tidal elevation was calculated from U.S. Dept. of Commerce Tide Tables (15). Since sediment and mussels were to be collected at specific intertidal elevations at the sites four times during a one-year period, a bench mark was established at each site to locate the 0.6-m tidal height (0.6-m to 0.9-m for mussels) for resampling throughout the study. The bench mark consisted of a 2-inch steel pipe driven into the ground or the use of prominent features of natural bedrock. The height of each bench mark above the 0.0-m tidal elevation was measured with a transit and stadia rod. Compass bearings were taken on reference points from the bench mark to help relocate the bench mark should it be destroyed. Detailed maps of a sampling area were also made so that the specific sampling sites could be readily relocated. Location maps with a site photograph, directions to the sampling sites, general description of their topography, and predominant water forces appear in Appendix II.

Two samples of sediment were taken at opposite corners of a 54 x 54 cm quadrat at each of 10 random points along the 30-m line. One sample from each point was then used to make a single composite sample. The samples were taken with a 5.5-cm dia. x 2-cm height aluminum coring device (47 cm^3) and a stainless-steel spatula (Fig. 6). Both had been rinsed previously with dichloromethane to prevent hydrocarbon contamination. These implements were rinsed with distilled water between each subsample collection. The 0.47-L glass storage jars and the aluminum foil used as a lid seal had been previously rinsed with dichloromethane. Each jar, containing approximately 0.47-L of composite sample, was stored on ice in the field and at -20°C in the laboratory prior to analysis. During the spring and summer, triplicate samples were collected at six sites to be used in the Beach Variability Study.

A Mussell sample consisting of 30 mussels 3-cm to 5-cm long was collected randomly within the 0.6-m to 0.9-m tidal height along the 30-m line placed on the beach (where possible). Two composite samples were collected and placed in solvent-rinsed, 0.94-L glass storage jars which had lid seals of aluminum foil previously rinsed with dichloromethane. Samples were collected four times at three-month intervals from February, 1977, to February, 1978. Two seven-day periods coinciding with low-tides were required to obtain samples from all of the sites. Since there was an approximate ten-day separation between suitable low-tide periods, a set of samples was usually completed within 25 days.

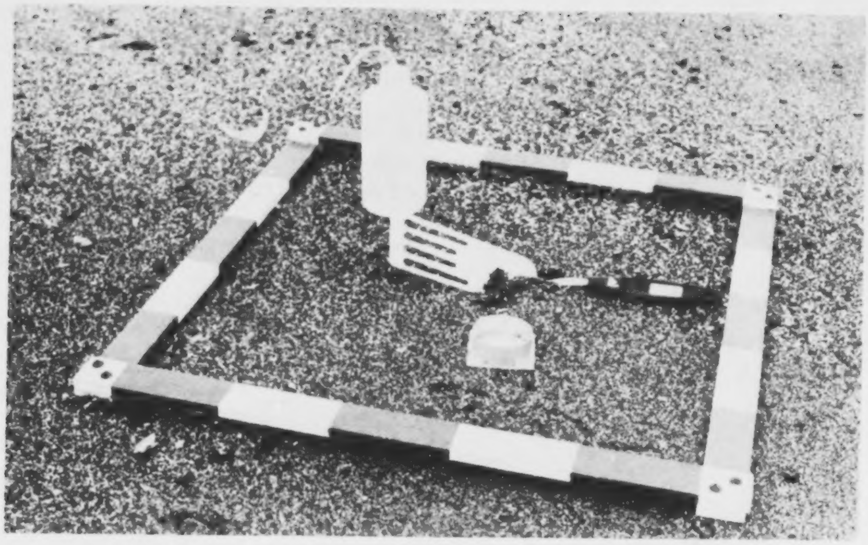

Figure 6. Sediment sampling implements framed with 54 x 54 cm sample quadrat. Foreground, aluminum coring device; center, stainless-steel spatula; background, teflon wash bottle with distilled water.

Field Observations. Physical hydrographic and atmospheric information collected during each sampling period included air, sediment, and water temperature; salinity; stage and range of tide; surf conditions; wind vector; and atmospheric conditions. Physical characteristics of each beach were recorded (Appendix I), and observations for any visible evidence of oil contamination (oil slicks) were made. Aerial and ground photographs (Appendix II), as well as movies, were taken at each site during daytime low tides.

Laboratory Studies. The sediment and mussel samples were analyzed for hydrocarbons according to the schemes in Figures 7 and 8. All laboratory procedures are included in Appendix III. Samples of the sediment composites were sent to the Department of Oceanography, University of Washington, Seattle, Washington (Dr. Richard W. Roberts, analyst), for total organic carbon and grain-size distribution analyses (19,20). Portions of homogenized mussel samples were sent to Bio-Med Research Laboratories, Seattle, Washington, for percent lipid analysis (21).

For hydrocarbon analysis in our laboratory, the samples were solvent extracted, the extracts filtered through a silica-gel column and then chromatographed on silica gel to obtain two hydrocarbon fractions. The first fraction contained the saturated hydrocarbons; the second contained the

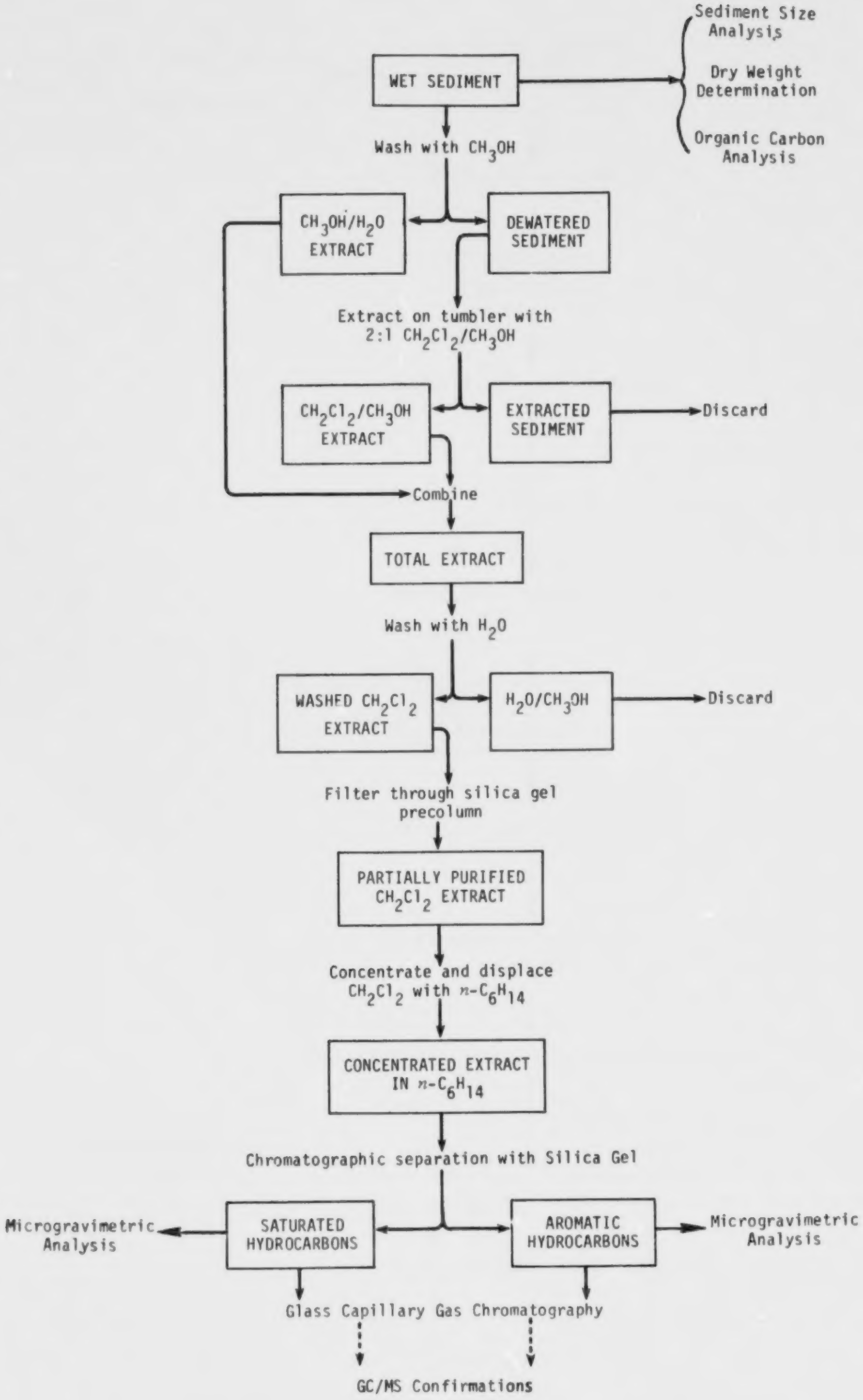
Sediment Size Analysis
Dry Weight Determination
Organic Carbon Analysis
WET SEDIMENT
Wash with CH_3OH
CH_3OH/H_2O EXTRACT
DEWATERED SEDIMENT
Extract on tumbler with 2:1 CH_2Cl_2/CH_3OH
CH_2Cl_2/CH_3OH EXTRACT
EXTRACTED SEDIMENT
Discard
Combine
TOTAL EXTRACT
Wash with H_2O
WASHED CH_2Cl_2 EXTRACT
H_2O/CH_3OH
Discard
Filter through silica gel precolumn
PARTIALLY PURIFIED CH_2Cl_2 EXTRACT
Concentrate and displace CH_2Cl_2 with n-C_6H_{14}
CONCENTRATED EXTRACT IN n-C_6H_{14}
Chromatographic separation with Silica Gel
Microgravimetric Analysis
SATURATED HYDROCARBONS
AROMATIC HYDROCARBONS
Microgravimetric Analysis
Glass Capillary Gas Chromatography
GC/MS Confirmations

Figure 7. Sediment analysis scheme

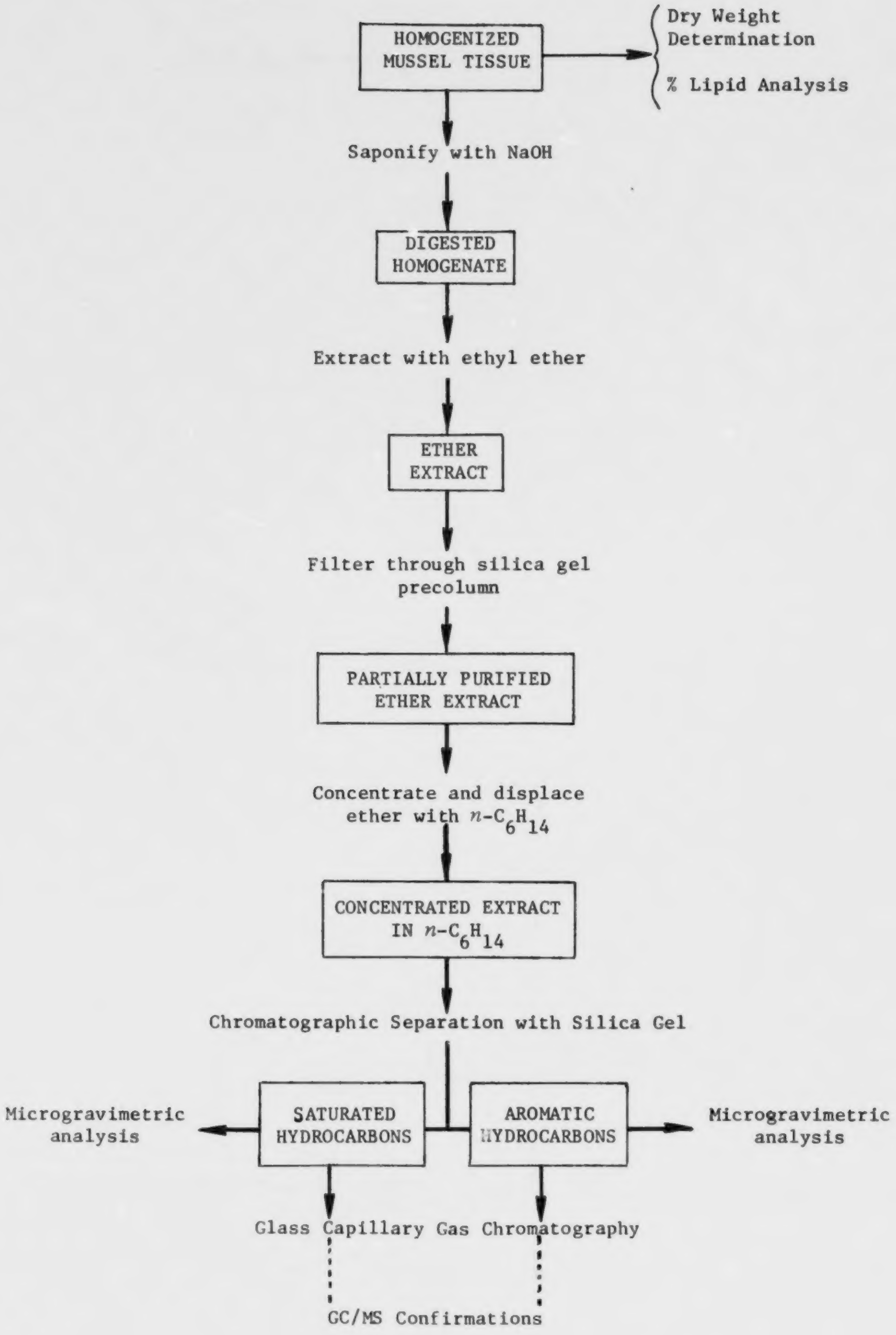
HOMOGENIZED MUSSEL TISSUE
Dry Weight Determination
% Lipid Analysis
Saponify with NaOH
DIGESTED HOMOGENATE
Extract with ethyl ether
ETHER EXTRACT
Filter through silica gel precolumn
PARTIALLY PURIFIED ETHER EXTRACT
Concentrate and displace ether with n-C_6H_{14}
CONCENTRATED EXTRACT IN n-C_6H_{14}
Chromatographic Separation with Silica Gel
Microgravimetric analysis
SATURATED HYDROCARBONS
AROMATIC HYDROCARBONS
Microgravimetric analysis
Glass Capillary Gas Chromatography
GC/MS Confirmations

Figure 8. Mussel analysis scheme.

unsaturated hydrocarbons including the aromatic hydrocarbons. After concentration, these extract fractions were analyzed by glass capillary gas chromatography (GC) for pristane, phytane, C_{10}-C_{31} n-alkanes, and the aromatic compounds listed in Table 3. Glass capillary GC combined with computerized mass spectrometry (MS) was used to confirm the identity of reported aromatic hydrocarbons. Each fraction was also analyzed microgravimetrically to measure total saturated hydrocarbons and total unsaturated hydrocarbons.

Table 3. Analyses performed on sediment and mussel samples.

Analysis	Samples	
	Sediments	Mussels
Dry weight	X	X
% lipid		X
Total organic carbon	X	
Texture and color	X	
Total aliphatic hydrocarbons	X	X
Total aromatic hydrocarbons	X	X
Individual aliphatic hydrocarbons[1]	X	X
Individual aromatic hydrocarbons[2]	X	X

[1] n-Alkanes from C_{12} to C_{31}, pristane, phytane.

[2]
- n-propylbenzene
- i-propylbenzene
- naphthalene
- 1-methylnaphthalene
- 2-methylnaphthalene
- biphenyl
- dibenzothiophene
- phenanthrene
- anthracene
- fluoranthene
- pyrene
- methylphenanthrene
- chrysene
- benz(a)anthracene
- benzo(e)pyrene
- benzo(a)pyrene
- perylene

Statistical Treatment and Data Management. For each quarter, the average and standard deviation was determined for the concentration of selected hydrocarbons in sediment and mussel samples from each site. The averages were assumed to be distributed normally. The standard deviation times 1.96 (1.96 x S.D.) was arbitrarily used to define the bounds about the mean within which 95% of the values should fall. By chance alone, one observation in twenty should fall outside these bounds.

The laboratory and field data were tabulated on sheets developed from format file type 044, NODC, for transfer to punch cards. After editing and correction, one complete set of data cards was transferred to NOAA's Seattle EDIS representative, and another set was stored at NAF. The hydrocarbon data are included in Appendix IV. All data are available from NODC (Appendix I).

Results

Site locations, field conditions at the time of sampling, and all data resulting from chemical analyses are recorded on computer punch cards and archived by NODC of NOAA's EDIS (Appendix I-2). A summary of the analytical results follows.

Field Observations. Oil slicks or other overt evidence of oil contamination were not observed at any of the sites during the one-year study. Physical changes in the beaches were unnoticeable except at Cherry Point, March Point and Kydaka Point. At Cherry Point, the surf washed away the sand at the 0.6-m tidal height after spring sampling. This resulted in a cobble beach with sand interspersed among the cobble. Fall storms probably removed some of the finer sediment at March Point, resulting in larger patches of coarse sediment. The Hoko River changed course during a fall flood, rendering the mussel sampling rocks at Kydaka Point inaccessible for the fall collection.

Mussels in bedrock areas were usually clustered, whereas in cobble areas they were more evenly distributed along a contour. Bedrock areas existed at Baadah Point, Kydaka Point, Pillar Point, Tongue Point, Alexander Beach, and Legoe Bay. Heavy riprap existed at Keystone and March Point. Mussels were absent or present in quantities too small to sustain sampling throughout the study at Dungeness Spit, False Bay, Shannon Point, and Cherry Point.

Total Saturated and Total Unsaturated Hydrocarbons. The measurement of total saturated hydrocarbons is the weight of extractable material present in the fraction that is eluted from the silica column with petroleum ether. The fraction eluted from the column with 40% dichloromethane in petroleum ether was analyzed to determine the total unsaturated hydrocarbons. In both cases the results included contributions from all material present in that silica-gel eluate, not just from the individual hydrocarbons selected for GC quantitation. The data in Table 4 show that the amounts of both saturated and unsaturated hydrocarbons were generally many times higher in mussels than sediments; e.g., the average values for unsaturated hydrocarbons are about 100 times higher in mussels than in sediments.

Gas chromatographic analysis. The gas chromatographic conditions are listed in Appendix III. The detection limit for most hydrocarbons was about 0.1 ng/g dry weight of sediment and about 5 ng/g dry weight of mussel tissue. The differences in these detection limits are due to differences in dry weight of samples analyzed (*ca.* 80 g dry weight of sediment compared to *ca.* 1.5 g mussel tissue).

The concentrations of pristane, phytane, the C_{10} through C_{31} *n*-alkanes, and selected aromatic hydrocarbons in sediments and mussels are reported in Appendix IV. The data were summarized by (1) adding the concentrations of the C_{12} to C_{20} *n*-alkanes (ΣSelected Alkanes), and by (2) adding the concentrations of the following aromatic hydrocarbons: naphthalene, 2-methylnaphthalene, 1-methylnaphthalene, 2,6-dimethylnaphthalene, 2,3,5-trimethylnaphthalene, phenanthrene, anthracene, 1-methylphenanthrene, benzo(e)pyrene, and benzo(a)pyrene (ΣSelected Aromatic Hydrocarbons). The results of these sums are reported in Table 5. The average value for the ΣSelected Alkanes in sediment was highest at Ediz Hook (150 ng/g dry weight) and second highest at

Table 4. Total saturated and total unsaturated hydrocarbons in quarterly samples of sediment and mussel tissue.

SEDIMENT

SITE	TOTAL SATURATED HYDROCARBONS ug/g dry weight					TOTAL UNSATURATED HYDROCARBONS ug/g dry weight				
	SP	SU	FA	WI	$\bar{x}$[1]	SP	SU	FA	WI	$\bar{x}$
1. Birch Pt.	3.4	1.1	(36)	2.2	2.2	4.9	5.5	6.2	2.2	4.7
2. Cherry Pt.	2.8	4.4	2.9	3.1	3.3	1.4	3.3	2.5	1.4	2.2
3. Sandy Pt.	3.1	1.1	1.8	5.5	2.9	3.3	2.0	1.0	3.1	2.4
4. March Pt.	7.2	8.1	10	8.6	8.5	5.7	11	6.4	8.3	7.9
5. Shannon Pt.	6.9	3.1	0	1.7	2.9	7.4	3.4	3.1	2.1	4.0
6. Alexander Beach	2.9	3.2	3.1	1.6	2.7	3.2	2.4	(13)	2.2	2.6
7. Fort Casey	1.0	1.9	0.8	0.8	1.1	2.2	0.5	0.8	0.04	0.9
8. Keystone	- - - - - - - - -MUSSELS ONLY- - - - - - - - - - -									
9. Naval Air Station	1.2	2.5	0.4	2.0	1.5	0.4	2.2	0.2	0.3	0.8
10. False Bay	1.9	2.3	2.4	2.5	2.3	2.8	3.0	5.5	1.5	3.2
11. Andrews Bay	7.6	3.0	2.7	2.6	4.0	(14)	3.7	1.6	0.4	1.9
12. Westcott Bay	- - - - - - - - -MUSSELS ONLY- - - - - - - - - - -									
13. Legoe Bay/Lummi Is.	- - - - - - - - -MUSSELS ONLY- - - - - - - - - - -									
14. Cape George	1.2	0.7	1.1	2.6	1.4	2.1	2.2	0.7	1.5	1.6
15. Dungeness/3 Crabs	3.8	5.8	1.8	3.3	3.7	9.9	6.2	4.4	7.5	7.0
16. Dungeness Spit	1.9	1.5	0.01	1.4	1.2	0.8	0.1	0.3	4.7	1.5
17. Ediz Hook	19	23	18	13	18	7.1	6.3	5.1	1.2	5.0
18. Tongue Pt./Crescent Bay	2.3	3.3	1.6	2.0	2.3	5.7	6.9	2.0	2.4	4.3
19. Deep Creek Beach	6.3	3.0	0.8	3.6	3.4	7.1	1.2	0.4	1.7	2.6
20. Deep Creek	- - - - - - - - -MUSSELS ONLY- - - - - - - - - - -									
21. Pillar Point	2.5	3.4	(39)	3.0	3.0	5.2	7.5	6.7	4.3	5.9
22. Kydaka Pt.	4.8	2.2	2.3	3.2	3.1	4.3	1.6	1.6	0.4	2.0
23. Baadah Pt.	3.4	5.8	3.5	3.8	4.1	5.7	3.4	1.5	1.2	3.0

MUSSELS

SITE	TOTAL SATURATED HYDROCARBONS ug/g dry weight					TOTAL UNSATURATED HYDROCARBONS ug/g dry weight				
	SP	SU	FA	WI	$\bar{x}$	SP	SU	FA	WI	$\bar{x}$
1. Birch Pt.	95	15	7	39	39	210	340	390	160	280
2. Cherry Pt.	150	--	--	--	--	540	--	--	--	--
3. Sandy Pt.	2	16	26	110	39	260	180	230	140	200
4. March Pt.	60	25	30	320	110	320	370	320	210	310
5. Shannon Pt.	61	58	--	--	60	350	130	--	--	240
6. Alexander Beach	280	43	47	96	120	370	200	470	250	320
7. Fort Casey	- - - - - - - - -SEDIMENT ONLY- - - - - - - - - - -									
8. Keystone	99	26	19	200	86	470	110	190	250	260
9. Naval Air Station	77	29	90	340	130	370	500	280	380	380
10. False Bay	58	41	--	--	50	150	130	--	--	140
11. Andrews Bay	- - - - - - - - -SEDIMENT ONLY- - - - - - - - - - -									
12. Westcott Bay	14	3	22	19	15	110	690	130	250	300
13. Legoe Bay/Lummi Is.	49	34	42	110	59	230	260	280	260	260
14. Cape George	13	2	15	19	12	79	130	80	340	160
15. Dungeness/3 Crabs	20	12	22	10	16	450	110	230	320	280
16. Dungeness Spit	- - - - - - - - -SEDIMENT ONLY- - - - - - - - - - -									
17. Ediz Hook	250	78	160	330	200	760	400	180	660	500
18. Tongue Pt./Crescent Bay	52	35	15	47	37	130	130	180	220	165
19. Deep Creek Beach	- - - - - - - - -SEDIMENT ONLY- - - - - - - - - - -									
20. Deep Creek	59	0	6	6	18	96	500	240	310	290
21. Pillar Point	24	35	4	43	27	260	200	150	280	220
22. Kydaka Pt.	25	41	--	36	34	290	180	--	180	220
23. Baadah Pt.	250	250	130	200	210	220	200	150	310	220

[1] The mean for spring (SP), summer (SU), fall (FA), and winter (WI) quarters is denoted by $\bar{x}$. Numbers in parentheses are not included in the calculation of $\bar{x}$ due to suspected contamination.

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Table 5. Summary of hydrocarbon levels (ng/g dry weight of sample) in quarterly samples of sediment and mussel tissue analyzed by GC.

SEDIMENT

SITE	ΣSELECTED ALKANES ($n\text{C}_{12}$-C_{20})					ΣSELECTED AROMATIC HYDROCARBONS[1]				
	SP	SU	FA	WI	$\bar{x}$[2]	SP	SU	FA	WI	$\bar{x}$[2]
1. Birch Pt.	24	30	67	38	40	7	ND	ND	1	2
2. Cherry Pt.	34	54	16	27	33	7	15	11	3	9
3. Sandy Pt.	49	40	46	51	47	23	10	6	36	19
4. March Pt.	124	110	88	87	100	49	61	26	19	39
5. Shannon Pt.	34	60	32	26	38	12	6	1	3	6
6. Alexander Beach	20	15	34	16	21	4	3	ND	2	2
7. Fort Casey	7	41	26	27	25	1	ND	ND	2	1
8. Keystone	MUSSELS ONLY									
9. Naval Air Station	2	21	1	9	8		3	ND	1	1
10. False Bay	13	32	38	17	25	14	16	130[3]	7	42[3]
11. Andrews Bay	87	64	62	75	72	12	4	ND	5	5
12. Westcott Bay	MUSSELS ONLY									
13. Legoe Bay/Lummi Is.	MUSSELS ONLY									
14. Cape George	4	3	53	27	22	1	5	ND	ND	2
15. Dungeness/3 Crabs	93	73	56	120	86	15	18	ND	18	13
16. Dungeness Spit	10	21	1	23	14	2	3	ND	ND	1
17. Ediz Hook	190	140	120	130	150	18	9	ND	5	8
18. Tongue Pt./Crescent Bay	18	22	25	25	23	1	4	ND	2	2
19. Deep Creek Beach	74	48	21	58	50	18	9	8	3	10
20. Deep Creek	MUSSELS ONLY									
21. Pillar Point	28	29	57	30	36	2	3	ND	3	2
22. Kydaka Pt.	125	49	110	130	100	61	8	27	19	29
23. Baadah Pt.	67	62	39	50	55	31	30	6	7	19

MUSSELS

SITE	ΣSELECTED ALKANES ($n\text{C}_{12}$-$n\text{C}_{20}$)					ΣSELECTED AROMATIC HYDROCARBONS[1]				
	SP	SU	FA	WI	$\bar{x}$[2]	SP	SU	FA	WI	$\bar{x}$[2]
1. Birch Pt.	560	1100	350	370	600	140	ND	ND	36	44
2. Cherry Pt.	760	-	-	-	-	300	-	-	-	-
3. Sandy Pt.	500	580	780	701	640	100	ND	570	23	170
4. March Pt.	450	520	880	820	670	130	110	440	200	220
5. Shannon Pt.	210	580	-	-	400	120	110	-	-	115
6. Alexander Beach	1800	780	1300	1200	1300	180	ND	33	63	69
7. Fort Casey	SEDIMENT ONLY									
8. Keystone	960	630	980	890	870	550	16	ND	ND	140
9. Naval Air Station	880	520	1100	770	820	51	ND	ND	ND	13
10. False Bay	100	1300	-	-	700	530	760	-	-	650
11. Andrews Bay	SEDIMENT ONLY									
12. Westcott Bay	79	400	500	480	360	ND	ND	ND	ND	ND
13. Legoe Bay/Lummi Is.	92	880	1400	780	790	230	18	110	320	170
14. Cape George	46	1200	250	700	550	88	100	160	24	93
15. Dungeness/3 Crabs	580	570	750	620	630	90	270	ND	ND	90
16. Dungeness Spit	SEDIMENT ONLY									
17. Ediz Hook	1300	1100	2300	17000	5400	3100	92	4600	2100	2500
18. Tongue Pt./Crescent Bay	ND	410	320	320	260	ND	ND	13	ND	3.3
19. Deep Creek Beach	SEDIMENT ONLY									
20. Deep Creek	310	820	1000	600	680	ND	ND	ND	ND	ND
21. Pillar Point	480	320	280	120	300	ND	ND	ND	49	12
22. Kydaka Pt.	29	850	-	1100	660	ND	28	-	ND	9.3
23. Baadah Pt.	340	1200	530	750	710	85	270	330	98	200

[1] Aromatics selected for summation are listed on page 18 of the text.

[2] The mean of spring (SP), summer (SU), fall (FA), and winter (WI) quarters is denoted by $\bar{x}$.

[3] Omitting the value of 130 for the aromatics in the fall sediment from False Bay gives $\bar{x}$ = 12.

March Point and Kydaka Point (100 ng/g); the highest average value for mussels was 5400 ng/g at Ediz Hook, about 8 times higher than the average of the other average values. The highest average values for the Selected Aromatic Hydrocarbons in sediments were found at March Point, Kydaka Point, False Bay, Sandy Point and Baadah Point, e.g., 39, 29, 42, 19, 19 ng/g (dry weight) respectively. The highest average value for mussels was at Ediz Hook (2500 ng/g dry weight). The data in Appendix IV should be used to evaluate the summarized data. For example, Table 5 shows 4600 ng/g for the ΣSelected Aromatic Hydrocarbons for the Fall quarter at Ediz Hook, whereas the data in Appendix IV shows that one compound, 1-methylnaphthalene, accounted for 93% of the amount.

An interesting observation was that, when benzpyrenes were detected, both benzo(e)pyrene and benzo(a)pyrene were found, and at similar concentrations.

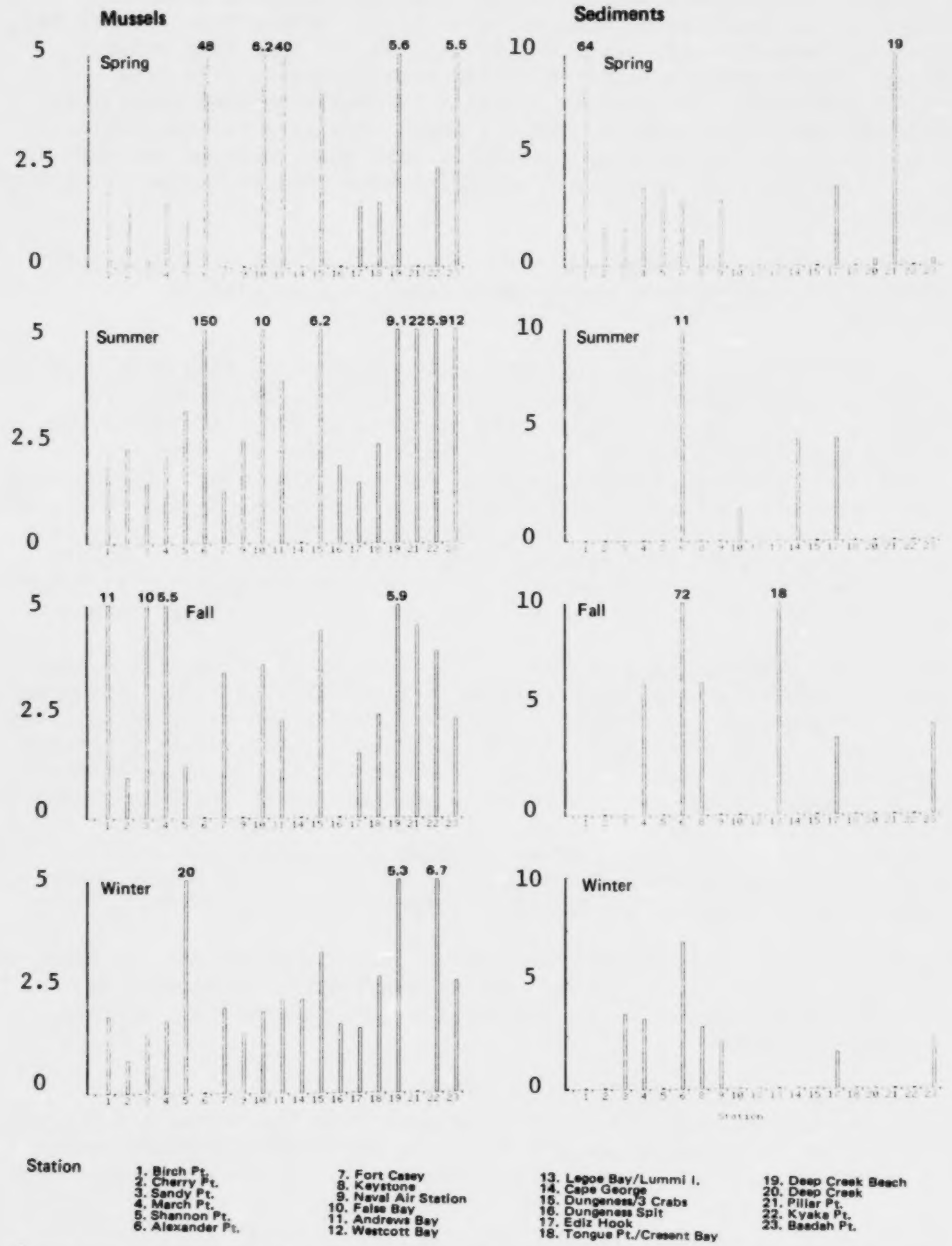
Graphs of the ratio of the concentrations of pristane to phytane for all sediment and mussel samples are shown in Figure 9. The ratios that are considerably greater than one indicate the presence of biological material, but petroleum hydrocarbons could also be present. Figure 10 shows the phenanthrene concentrations for the sediment and mussel samples. Phenanthrene was found consistently at March Point, False Bay, Ediz Hook, Kydaka Point, and Baadah Point. Figure 11 shows the benz(a)anthracene data for sediments and mussels. The compound was consistently found in March Point and False Bay sediments but only once in March Point mussels, and in two quarters in False Bay mussels and Ediz Hook mussels (i.e., 1600 ppb Ediz Hook winter mussels).

Total lipids and total solids in mussels. The amounts of total lipids and total solids in mussel tissues are reported in Table 6. The total lipids are reported on a dry weight basis because the hydrocarbons are reported on a dry weight basis and comparisons are facilitated. However, the values for total lipids (dry weight) is dependent to some degree on the amount of extractable water in the tissue; consequently the following comments on lipids are made on the original results of analyses on the wet tissue. Mussels contain a relatively small amount of lipid, since the complete range was between 0.7 and 3.1%, with only 3 composite samples having values over 2%. The uniformity of results precludes attributing differences to factors such as season or site.

The amount of solids ranged from 8.8% to 19.5%; conversely, the range of extractable water was 91.2% to 80.5%. The seasonal differences were not pronounced, but at 2/3 of the sites the samples taken in the fall had the lowest moisture contents.

Sediment Analysis. Total organic carbon (TOC) and sand-to-mud ratios from sediment grain-size analyses were used to characterize the sediment and are reported in Table 7. These values are about ten times lower than we have found for sub-tidal samples in some depositional areas of Central Puget Sound.

Figure 9. Pristane/phytane ratios for quarterly sediment and mussel samples.[1]



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[1] Stations at which pristane and/or phytane were not found are left blank, i.e. are given a value of 0.

Figure 10. Phenanthrene in quarterly sediment and mussel samples.

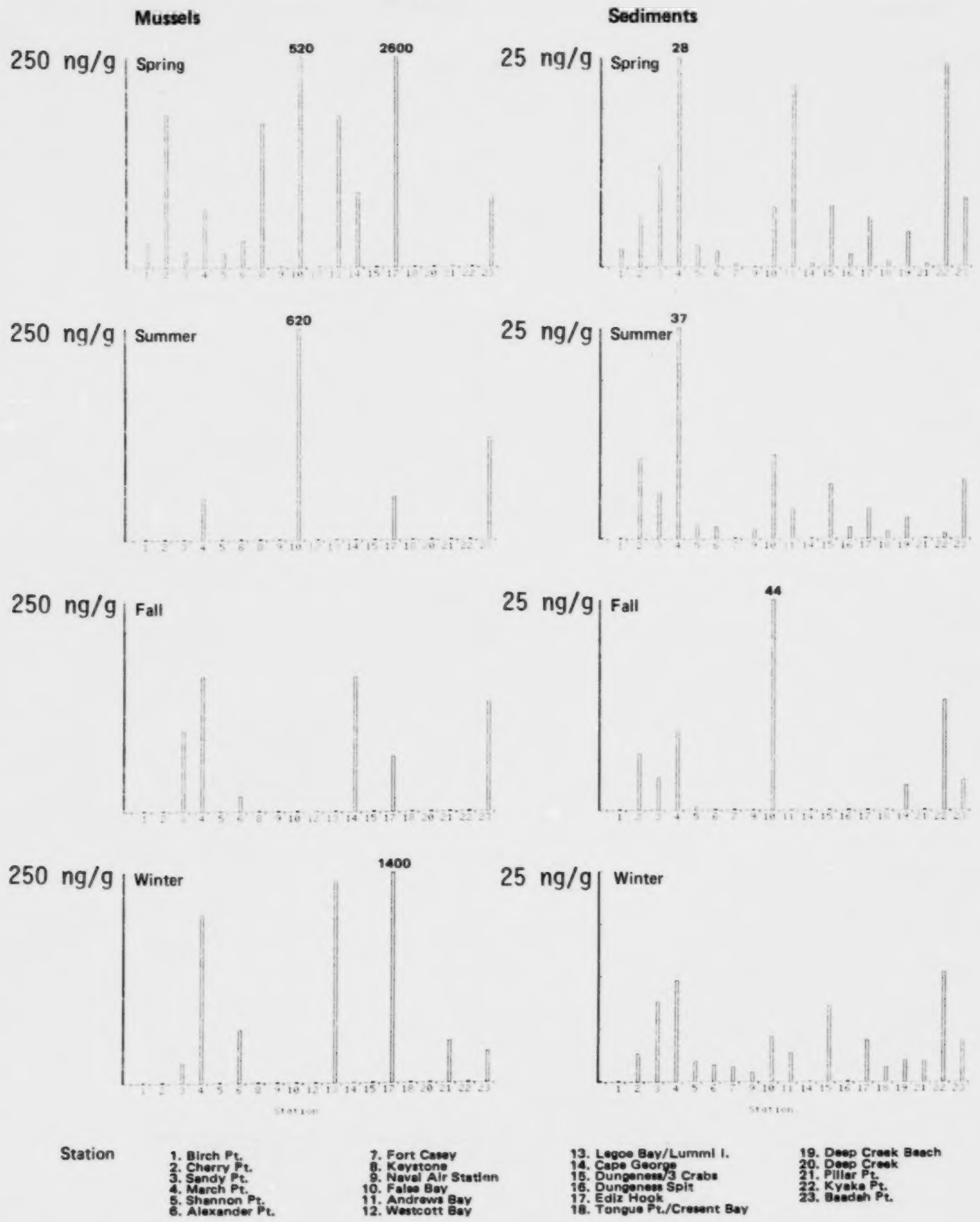

Figure 11. Benz[a]anthracene in quarterly sediment and mussel samples.

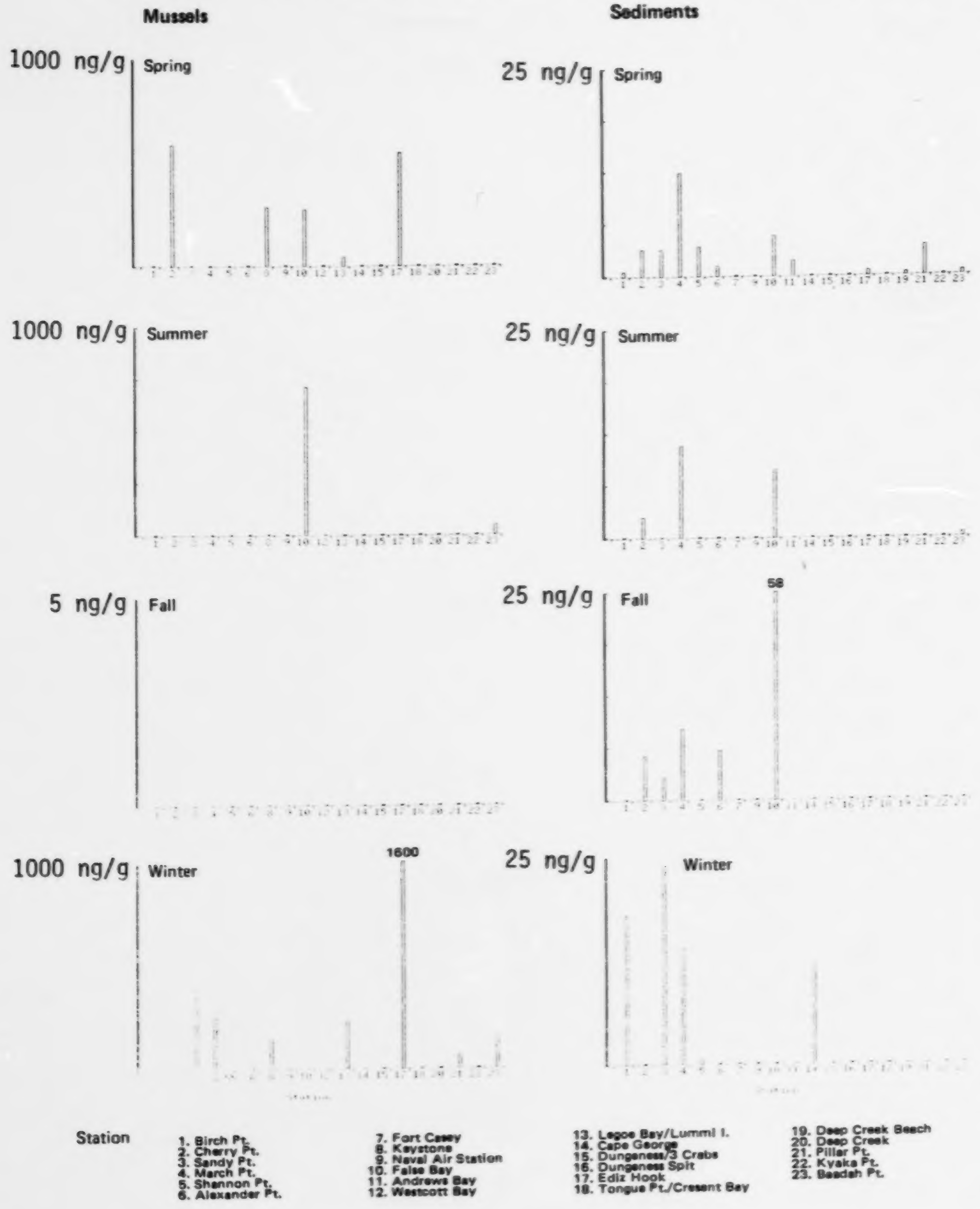

Table 6. Total lipids and total solids in mussel tissue.

SITE	TOTAL LIPID percent dry weight					TOTAL SOLIDS percent				
	SP	SU	FA	WI	x̄[1]	SP	SU	FA	WI	x̄
1. Birch Pt.	7.4	13.8	11.5	9.2	10.5	12.3	10.7	15.5	12.3	12.7
2. Cherry Pt.	7.5	--	--	--	--	8.8	--	--	--	--
3. Sandy Pt.	8.7	16.3	9.4	9.8	11.0	10.4	11.7	13.0	11.4	11.6
4. March Pt.	13.2	12.7	15.9	12.1	13.5	12.2	12.0	19.5	11.5	16.7
5. Shannon Pt.	10.4	12.5	--	--	11.5	12.3	13.6	--	--	13.0
6. Alexander Beach	11.9	10.7	14.1	12.4	12.3	13.5	15.4	18.1	15.7	16.0
7. Fort Casey	--	--	--	--	--	--	--	--	--	--
8. Keystone	12.7	11.0	12.5	8.8	11.3	11.0	13.5	12.6	12.5	12.4
9. Naval Air Station	11.9	12.7	10.2	8.0	10.7	13.1	14.7	14.2	14.0	14.0
10. False Bay	12.3	12.1	--	--	12.2	13.2	13.3	--	--	13.3
11. Andrews Bay	--	--	--	--	--	--	--	--	--	--
12. Westcott Bay	13.3	12.5	9.5	11.7	11.8	11.7	10.3	12.7	11.3	11.5
13. Legoe Bay/Lummi Is.	12.2	10.0	10.8	11.6	11.2	14.6	14.0	16.8	11.9	14.3
14. Cape George	11.2	11.0	11.0	10.5	11.0	15.2	14.9	14.9	13.8	14.7
15. Dungeness/3 Crabs	10.6	9.0	9.4	6.5	8.9	11.6	12.8	14.1	10.9	12.4
16. Dungeness Spit	--	--	--	--	--	--	--	--	--	--
17. Ediz Hook	18.2	9.8	12.1	12.9	13.3	10.0	10.9	15.4	13.7	12.5
18. Tongue Pt./Crescent Bay	8.6	11.7	10.6	10.6	10.4	12.4	16.7	16.3	16.0	15.4
19. Deep Creek Beach	--	--	--	--	--	--	--	--	--	--
20. Deep Creek	9.7	8.1	9.9	8.8	9.1	9.5	12.1	12.6	12.0	11.6
21. Pillar Point	9.8	10.3	11.3	12.7	11.0	14.5	16.2	15.4	16.2	18.5
22. Kydaka Point	10.4	9.7	--	10.0	10.0	9.9	10.3	--	10.7	10.3
23. Baadah Pt.	11.2	18.8	10.4	12.5	13.2	16.3	15.5	17.5	14.7	16.0

[1] The average value of spring (SP), summer (SU), fall (FA), and winter (WI) quarters is denoted by x̄.

Table 7. Total organic carbon and sand-to-mud ratio for sediments.

SITE	TOC (%)					SAND/MUD RATIO				
	SP	SU	FA	WI	x̄[1]	SP	SU	FA	WI	x̄
1. Birch Pt.	0.22	0.16	0.37	0.14	0.22	50	84	18	59	53
2. Cherry Pt.	0.11	0.18	0.13	0.10	0.13	250	130	100	110	150
3. Sandy Pt.	0.17	0.18	0.25	0.19	0.20	69	99	100	47	79
4. March Pt.	0.19	0.14	0.27	0.15	0.19	50	33	25	86	49
5. Shannon Pt.	0.18	0.12	0.13	0.11	0.14	96	100	45	100	85
6. Alexander Beach	0.15	0.06	0.27	0.12	0.15	130	95	41	130	99
7. Fort Casey	0.11	0.07	0.11	0.12	0.10	240	180	160	240	210
8. Keystone	--	--	--	--	--	--	--	--	--	--
9. Naval Air Station	0.12	0.07	0.09	0.05	0.08	170	210	210	110	180
10. False Bay	0.14	0.14	0.36	0.13	0.19	140	52	64	43	75
11. Andrews Bay	0.10	0.14	0.14	0.11	0.12	98	130	88	130	110
12. Westcott Bay	--	--	--	--	--	--	--	--	--	--
13. Legoe Bay/Lummi Is.	--	--	--	--	--	--	--	--	--	--
14. Cape George	0.11	0.07	0.10	0.10	0.10	42	51	34	28	39
15. Dungeness/3 Crabs	0.38	0.31	0.27	0.42	0.35	8	11	10	3	8
16. Dungeness Spit	0.08	0.07	0.05	0.05	0.06	180	165	210	120	170
17. Ediz Hook	0.11	0.10	0.10	0.12	0.11	139	118	150	110	130
18. Tongue Pt./Crescent Bay	0.16	0.16	0.12	0.14	0.15	99	110	85	77	93
19. Deep Creek Beach	0.21	0.07	0.10	0.13	0.13	64	190	170	56	120
20. Deep Creek	--	--	--	--	--	--	--	--	--	--
21. Pillar Point	0.21	0.20	0.19	0.19	0.20	70	49	58	52	57
22. Kydaka Pt.	0.12	0.08	0.09	0.24	0.13	80	170	91	140	120
23. Baadah Pt.	0.12	0.10	0.12	0.16	0.13	150	180	150	150	160

[1] The average value of spring (SP), summer (SU), fall (FA), and winter (WI) quarters is denoted by x̄.

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Discussion

We assessed the data obtained in this study for petroleum contamination at the 23 sites. The sites used in this study were relatively free from petroleum contamination. For the most part, the highest concentrations of individual hydrocarbons indicative of petroleum were present in sediments at low ppb. We found values about 100 to 1000 times higher in sub-tidal sediments from some urban depositional areas in Puget Sound.

Evaluation of Hydrocarbons at Sampling Sites. The hydrocarbon data from the samples indicate the presence of low levels of petroleum at Ediz Hook, March Point, Baadah Point, Kydaka Point, Cherry Point, Sandy Point, and False Bay. Individual hydrocarbons from petroleum and/or biological sources were evident at Birch Point, Pillar Point, Dungeness/Three Crabs, Shannon Point and Cape George (Tables 5, 8 and Appendix IV). The sites not mentioned above appeared to be more pristine than Dungeness/Three Crabs, a site considered to be relatively pristine. The lowest individual hydrocarbon levels were measured at the Naval Air Station on Whidbey Island. Fort Casey, Crescent Bay, Alexander Beach, Cape George and Dungeness Spit had similarly low levels. Shannon Point, Birch Bay, Pillar Point, Andrews Bay, Deep Creek Beach and False Bay had slightly higher levels than the Naval Air Station.

The sites that had elevated levels of hydrocarbons which might indicate the presence of petroleum are discussed below.

Ediz Hook. This site is on the harbor side of a spit facing the city of Port Angeles (population: *ca.* 16,000). There are lumber and paper industries nearby and considerable boating activity in Port Angeles harbor. Several small creeks empty into the harbor. The sampling site is protected from direct waves from the Strait of Juan de Fuca, but is subjected to surge waves from shipping activity.

The amounts of total saturated and total unsaturated hydrocarbons from Ediz Hook sediments were among the highest found at any of the sites (Table 4). Measurable levels of both individual alkanes and aromatic hydrocarbons, as determined by gas chromatography, were present in all mussel samples collected at Ediz Hook. Statistical treatment of the hydrocarbon data showed levels of individual hydrocarbons to be consistently higher at Ediz Hook than the all-site average plus 1.96 x S.D. for that compound. The average of the quarterly ΣSelected Alkanes for sediments and mussels (Table 5) was highest each quarter at Ediz Hook. The average of the quarterly ΣSelected Aromatic Hydrocarbons was the highest for Ediz Hook mussels, but the sediment value was close to the average for all sites.

In all the quarterly samples, the presence of alkyl-substituted aromatic hydrocarbons and the nearly even distribution of *n*-alkanes strongly suggest petroleum input. The slight predominance of odd carbon-number *n*-alkanes suggest only minor biogenetic input. It is interesting that 4300 ng/g of 1-methylnaphthalene found in the fall mussel sample. We have no clear explanation for the presence of this much 1-methylnaphthalene when 2-methylnaphthalene was not detected. These two compounds are usually found in comparable concentrations.

March Point. This sampling site is located on the northeast side of March Point, Fidalgo Island, adjacent to a boat launch area. Two major oil refineries, a large wood pulp mill, and the city of Anacortes (population about 8,000) are nearby. Marine flora and fauna were abundant at this site.

March Point sediment contained elevated levels of hydrocarbons relative to the other sites in this study. The microgravimetric results for sediments and mussels (Table 4) were high, the average value of the ΣSelected Alkanes in sediments was second highest, and the average value of the ΣSelected Aromatic Hydrocarbons was highest in sediments and second highest in mussels. Statistical treatment of the hydrocarbon data showed persistent levels of individual hydrocarbons outside the average values for all of the sites plus 1.96 x S.D. The n-alkanes did not show odd-carbon predominance and the pristane/phytane ratios were close to one. These results indicate the presence of petroleum contamination at March Point. Interestingly, March Point sediment samples generally had higher levels of the polynuclear aromatic hydrocarbons phenanthrene, pyrene, benzo(e)pyrene, and benzo(a)pyrene than any of the other sites. Alkanes and arenes were found in all quarterly mussel samples from March Point.

Baadah Point. This sampling site is at the edge of Neah Bay, an active fishing port. Waadah Island and a breakwater protect the area from direct waves from the Strait and could serve to hold spilled oil in the area. Both aliphatic and aromatic hydrocarbons were found in all quarterly mussel samples and sediment samples. The GC patterns and the hydrocarbon data indicate the presence of petroleum hydrocarbons. Statistical treatment of the sediment hydrocarbon data showed concentrations of certain compounds above the average plus 1.96 x S.D., but not for more than two quarters.

Kydaka Point. This site is along the Strait of Juan de Fuca near the mouth of the Hoko River. The entire area is subjected to heavy wash from the Strait of Juan de Fuca. The data indicate the presence of petroleum (Table 5).

Cherry Point. This site is exposed to the Strait of Georgia near Ferndale, Washington, between two oil refineries and an aluminum plant. Hydrocarbon levels in sediments were very low, mostly less than 10 ppb. High winds, wave action, and currents probably account for the comparatively low hydrocarbon levels at this site, despite its proximity to industrial activity known to put hydrocarbons into the environment. Mussels were available at Cherry Point only for the spring sampling. They contained measurable levels of both individual aliphatic and aromatic hydrocarbons. The consistently low level of hydrocarbons suggest that petroleum hydrocarbons are not accumulating in this high-energy beach area.

False Bay. The n-alkanes from the sediment samples were present at very low concentrations and exhibited significant odd-carbon-number predominance, implying the presence of biological hydrocarbons. Low levels of aromatic hydrocarbons were measured in these sediments. The spring, summer, and winter levels were less than 10 ppb for aromatic compound except fluoranthene (20 ppb in the spring sediment). The fall sediment contained higher levels, e.g., 170 ppb fluoranthene. Mussel samples were available at False Bay during spring and summer quarters only. These samples contained low levels of aromatic hyrocarbons; however, phenanthrene and fluoranthene were about

500 ppb in both spring and summer samples. Apparently, then, the hydrocarbons in False Bay samples are from both biological and fossil sources.

Andrews Bay. The spring sediment sample contained high concentrations of pristane (and/or some compound that interfered with the analysis of pristane) and phytane. This ratio was closer to 1 for the other samplings. The n-alkanes and aromatic hydrocarbons in the spring sediment sample indicate the presence of petroleum. Based on the n-alkane distribution, it was probably a distilled fuel oil, as opposed to a crude oil or a residual oil. Samples from the other seasons showed much lower hydrocarbon levels. Mussel samples were not collected at Andrews Bay. Other than the one spring sediment sample, the Andrews Bay samples contained levels of hydrocarbons similar to those at Whidbey Island NAS (which contained the lowest levels of hydrocarbons measured in this study).

Dungeness/Three Crabs. Individual aliphatic and aromatic hydrocarbons were present in all samples from Dungeness/Three Crabs. Sediment samples all contained n-alkanes; however, the odd carbon numbered n-alkanes predominated. Aromatic hydrocarbons were found in Dungeness/Three Crabs sediment samples, but at concentrations less than 10 ppb (except for chrysene in the spring sample at 30 ppb). The data from these samples indicate this area to be relatively free of petroleum.

Sandy Point. This site has extensive mud flats and is exposed to high wind and wave action from the Strait of Georgia. Commercial fishing for Dungeness crab occurs in this area. Regularly distributed n-alkanes were found in all sediment samples, suggesting petroleum input. Alkanes were measured in extracts from all sediment and mussel samples. Aromatic hydrocarbons were measured in extracts from all sediment samples, but at the ppb level. Of the 24 aromatic compounds quantitated, none were found in the extract from summer mussels, and only three or four aromatic compounds were detected in the other extracts from mussel samples. The statistical treatment of the sediment data showed that certain hydrocarbon levels were elevated, but not for more than two quarters. Petroleum appears to be present at Sandy Point at levels similar to those at Dungeness/Three Crabs, which is a relatively pristine area.

Shannon Point. Mussels were collected only in the spring and summer. Alkanes were present in sediment and mussel extracts, at low ppb concentrations (Appendix 4). Aromatic compounds were measured in sediment and mussel extracts, but only 2 of the 24 compounds quantitated were found in the fall sediment, spring mussel, and summer mussel extracts. Shannon Point contains generally lower concentrations of petroleum hydrocarbons than Dungeness/Three Crabs.

Individual hydrocarbons

Naphthalene. Naphthalene is considered relatively labile and is subject to both chemical and biological oxidations. It is found in the water soluble fraction from petroleum. It is also considered a toxic component when present in water. Sediments from 18 of the sites contained naphthalene during the spring and/or summer. The highest concentration was 4 ng/g, dry weight, which is about 2 orders of magnitude lower than the concentration we found in a subtidal sediment sample from a moderately polluted urban area of Puget Sound. Naphthalene was not detected in the fall and winter sediment samples. Mussels from 8 sites contained naphthalene, although at 5 of these sites it was present at only one sampling. Mussels at Kydaka Point and Legoe Bay contained naphthalene only in the summer samples, while mussels at Alexander Beach, March Point and Tongue Point contained naphthalene only in the fall. Naphthalene was found in mussels at: Ediz Hook in both summer and fall samples; Cape George in both summer and winter samples; and Baadah Point in the summer, fall and winter samples. Spring samples did not contain detectable levels of naphthalene at any of the sites. The three samples from Baadah Point and one from Ediz Hook had the highest concentration (approximately 40 ng/g dry weight). The low concentrations of naphthalene, and the few times it was found in mussels at more than one sampling, suggests that the naphthalene found in the mussels reflects recent exposures to low concentrations.

Phenanthrene. Phenanthrene is found in many petroleum products and is not considered to be a natural biological compound. The phenanthrene data generally support the conclusion, noted above, that there was evidence of fossil fuels in samples from Ediz Hook, March Point, Kydaka Point, Sandy Point, Shannon Point, False Bay, Baadah Point, and Cherry Point. Phenanthrene was found in sediment samples each quarter from Cherry Point, Sandy Point, March Point, Shannon Point, False Bay, Deep Creek Beach, Kydaka Point, and Baadah Point, and in three quarters from Alexander Beach, Andrews Bay, Dungeness/Three Crabs, and Ediz Hook (Figure 10). Phenanthrene was detected in all four quarterly mussel samples from March Point, Ediz Hook, and Baadah Point. March Point and False Bay generally had the highest concentrations of phenanthrene in sediment samples, whereas the Ediz Hook winter samples had the highest concentration in mussels. The concentrations generally were lowest in the fall samples. A greater number of the spring mussel and sediment samples contained phenanthrene, and generally the levels in spring samples were higher than in samples from the other samplings.

Benz(a)anthracene. Benz(a)anthracene, though present less often than phenanthrene, was found in sediment from March Point, Sandy Point, Cherry Point, and False Bay, and in two samplings in False Bay and Ediz Hook mussels (False Bay mussels were only collected twice).

Petroleum Contamination. The microgravimetric results for hydrocarbons in sediments imply that the sites studied are relatively free of petroleum. Clark & MacLeod's review of published studies (21) showed that petroleum polluted beaches generally contained 100 μg or more of total hydrocarbons per gram of dry sediment. Generally values were over 1000 μg/g. In the present study, all results for total hydrocarbons were less than 25 μg/g, and most were less than 10 μg/g (Table 4).

One of the questions generally asked "What amount of petroleum is present?" Since only a fraction of any oil is included in analyses of individual compounds, we attempted to relate the concentration of one compound to a quantity of reference oil in order to hypothesize about the amount of petroleum at the different beaches. The following argument can thus be developed for the purpose of discussion: If one assumes the even numbered n-alkanes (such as n-C_{20}) all came from petroleum, one may correlate the concentration of that compound to a concentration of a reference sample of petroleum. If crude oil containing 0.2% n-C_{20} (wt) is used as a reference petroleum, then 1 ppb of n-C_{20} in a sample would correspond to 1/2 microgram/gram (μg/g) of crude oil in that sample. Following this reasoning, none of the sediment samples contained more than 10 μg/g (ppm) of oil (Table 8).

Table 8. Hypothetical values of petroleum present in dry sediment assuming all n-$C_{20}H_{42}$ came from crude oil containing 0.2% n-$C_{20}H_{42}$.

		Spring	Summer	Fall	Winter
		ug/g	ug/g	ug/g	ug/g
1.	Birch Pt.	1	2	1	0.5
2.	Cherry Pt.	2	2	1	2
3.	Sandy Pt.	2	3	3	3
4.	March Pt.	10	8	4	5
5.	Shannon Pt.	1	2	4	2
6.	Alexander Beach	3	1	2	2
7.	Fort Casey	0.7	3	2	1
8.	Keystone		- - - -MUSSELS ONLY- - - -		
9.	Naval Air Station	0.2	2	0.3	0.6
10.	False Bay	1	3	4	1
11.	Andrews Bay	3	3	5	5
12.	Westcott Bay		- - - -MUSSELS ONLY- - - -		
13.	Legoe Bay/Lummi Is.		- - - -MUSSELS ONLY- - - -		
14.	Cape George	0.2	0.3	2	1
15.	Dungeness/3 Crabs	5	4	4	6
16.	Dungeness Spit	1	1	0.3	1
17.	Ediz Hook	10	10	7	8
18.	Tongue Pt./Crescent Bay	2	2	2	2
19.	Deep Creek Beach	6	4	3	4
20.	Deep Creek		- - - -MUSSELS ONLY- - - -		
21.	Pillar Point	2	3	4	3
22.	Kydaka Pt.	6	4	7	8
23.	Baadah Pt.	4	5	3	3

TEMPORAL VARIABILITY STUDY

Sediment and mussel samples were collected at March Point six times at approximately 2 week intervals beginning September 21, 1977, to determine whether hydrocarbon concentrations would indicate major short-term changes that might not be observed by quarterly monitoring. For example, would individual hydrocarbons that are found in petroleum be present at high concentrations at one sampling and decrease significantly by the next sampling, or would these values be rather consistent? Consistent values might imply that the compounds are removed by the various processes at about the same rate at which they are added.

Methods and Materials

The same sampling and analysis protocols were followed as in the Hydrocarbon Baseline Study.

Results and Discussion

Results from the sediment and mussel analyses are summarized in Table 9 and the data for the individual compounds are reported in Tables 10 and 11. Since this study was done to evaluate possible short term changes, it is probably best to evaluate the data for individual compounds. The values in Tables 10 and 11 are very low. These results are reported as parts per billion (ppb) and as such they might appear to be more variable than they actually are. For example, the data for $\underline{n}$-$C_{14}H_{30}$ in Table 10 ranges from 4.3- to 7.8 ppb which is 0.043 to 0.078 ppm. In other words, there is little difference between 4.3 ppb and 7.8 ppb. The data for the alkanes are surprisingly consistent. The data for the aromatic compounds appear to be more variable than data for the alkanes. For example, the results for some compounds in the sample collected September 21 are different from those from some other samples by about 30 times; the value for benzo(e)pyrene in sediments is 34 for the September 21 sample vs. 1.2 for the November 1 sample. The values for some of the alkanes in mussel samples in Table 11 are much higher than those for sediments. For example, the average value for $\underline{n}$-$C_{15}H_{32}$ in sediments is 12 ppb, and in mussels is 293 ppb. The detectable concentration for hydrocarbon compounds in the mussel samples is about 10 ppb and values of 20, 40, even 60 are low concentrations.

These data generally show that the individual compounds were not introduced as a slug of petroleum that disappeared with subsequent samples. The data for the quarterly samplings (Appendix IV) are similar to the data in Tables 10 and 11, and imply that hydrocarbons are present at a rather constant level.

Table 9. Summary of analytical results from Temporal Variability Study samples at March Point.

	1977					
	9/21	10/6	10/14	11/1	11/17	11/30
MICROGRAVIMETRIC DETERMINATION (μg/g dry)						
Sediment						
Total sat'd hydrocarbons	6.4	9.0	10	4.7	7.0	5.3
Total unsat'd hydrocarbons	9.4	6.9	6.4	4.5	5.6	4.2
Mussels						
Total sat'd hydrocarbons	55	60	30	38	54	17
Total unsat'd hydrocarbons	190	360	320	140	140	110
GC ANALYSIS (ng/g dry)						
Sediment						
ΣSelected Alkanes (n-C_{12}-C_{20})	113	82	84	90	98	98
ΣSelected Aromatic Hydrocarbons[1]	27	13	26	26	40	37
Mussels						
ΣSelected Alkanes (n-C_{12}-C_{20})	890	1500	880	700	790	680
ΣSelected Aromatic Hydrocarbons[1]	ND	140	412	120	550	190
MUSSEL ANALYSES						
% Lipid	19.0	15.9	15.9	12.0	14.7	9.4
%Dry weight	17	18	19	16	17	16
SEDIMENT ANALYSES						
% Organic Carbon	0.18	0.27	0.27	0.21	0.25	0.16
Sand/Mud Ratio	25	25	25	24	31	41

[1] Selected aromatics are listed in text on page 18.

Table 10. Concentration of alkanes and aromatic hydrocarbons (ng/g dry) in March Point sediments at two-week intervals, from 9/21 to 11/30.

n-alkane	DATE OF SAMPLE					
	9/21	10/6	10/14	11/1	11/17	11/30
C_{10}	ND	ND	ND	ND	ND	ND
C_{11}	ND	ND	ND	ND	ND	ND
C_{12}	4.5	3.9	3.8	2.5	3.4	4.8
C_{13}	5.2	4.0	7.7	3.3	3.7	5.6
C_{14}	7.8	5.0	4.3	4.4	5.1	6.8
C_{15}	16	10	11	15	11	11
C_{16}	13	7.2	5.9	9.3	9.1	9.0
C_{17}	22	18	18	15	21	21
Pristane[1]	20	15	23	11	15	10
C_{18}	14	10	8.6	11	13	11
Phytane[1]	8.6	6.0	4.2	4.4	7.4	4.4
C_{19}	18	15	16	19	21	19
C_{20}	12	8.6	8.3	10	11	9.9
C_{21}	12	9.5	10	13	12	11
C_{22}	10	7.1	7.7	8.0	11	12
C_{23}	19	14	16	16	18	15
C_{24}	11	8.2	8.7	7.0	13	10
C_{25}	17	19	21	15	28	39
C_{26}	9.1	6.7	8.3	5.5	13	9.8
C_{27}	26	35	41	27	44	82
C_{28}	7.7	8.8	9.7	5.4	13	11
C_{29}	23	29	3.2	21	31	26
C_{30}	13	2.3	19	11	5.8	4.9
C_{31}	13	19	24	14	19	14

Aromatic Hydrocarbon	DATE OF SAMPLE					
	9/21	10/6	10/14	11/1	11/17	11/30
o-Xylene	ND	ND	ND	ND	ND	ND
Isopropylbenzene	ND	ND	ND	ND	ND	ND
n-Propylbenzene	ND	ND	ND	ND	ND	ND
Indan	ND	ND	ND	ND	ND	ND
1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND	ND	ND
Naphthalene	ND	ND	ND	ND	ND	ND
Benzothiophene[2]	ND	ND	<0.040	ND	ND	ND
2-Methylnaphthalene	ND	ND	2.9	ND	ND	ND
1-Methylnaphthalene	ND	ND	1.6	ND	ND	ND
Biphenyl	1.4	1.1	0.030	1.2	1.2	1.1
2,6-Dimethylnaphthalene	3.0	0.24	0.64	2.3	1.6	0.22
2,3,5-Trimethylnaphthalene	1.5	0.39	0.63	0.12	0.36	0.35
Fluorene	3.7	0.97	0.29	2.5	1.8	1.8
Dibenzothiophene[2]	1.7	0.48	<0.060	<0.030	1.1	<0.030
Phenanthrene	48	4.6	9.6	17	17	15
Anthracene	7.8	1.1	1.5	2.5	3.1	3.1
1-Methylphenanthrene	<0.030	0.63	0.48	1.2	1.5	1.6
Fluoranthene	83	11	11	18	28	26
Pyrene	67	3.5	8.3	16	22	79
Benz[*a*]anthracene	42	2.2	8.5	8.3	17	14
Chrysene	92	3.5	6.5	2.9	10	10
Benzo[e]pyrene	34	4.6	4.2	1.2	12	11
Benzo[a]pyrene	16	1.2	4.2	1.3	4.9	4.4
Perylene	5.8	0.44	0.73	<1.0	4.6	3.8

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[1] a branched alkane

[2] a sulfur-substituted aromatic hydrocarbon

ND=not detected

Table 11. Concentration of alkanes and aromatic hydrocarbons (ng/g dry) in March Point mussels at two-week intervals, from 9/21 to 11/30.

	DATE OF SAMPLE					
n-alkane	9/21	10/6	10/14	11/1	11/17	11/30
C_{10}	220	420	410	330	140	68
C_{11}	210	360	360	270	140	79
C_{12}	150	240	250	150	81	51
C_{13}	84	120	110	80	84	59
C_{14}	84	140	81	78	160	35
C_{15}	350	460	190	290	270	200
C_{16}	130	380	52	ND	33	250
C_{17}	93	130	87	42	88	34
Pristane[1]	260	650	620	240	280	340
C_{18}	ND	5.7	19	ND	24	ND
Phytane[1]	ND	120	100	53	52	58
C_{19}	ND	ND	63	41	20	35
C_{20}	ND	26	29	22	33	20
C_{21}	ND	86	31	20	34	31
C_{22}	ND	38	32	16	36	27
C_{23}	57	99	85	72	84	71
C_{24}	ND	26	18	ND	34	29
C_{25}	41	50	38	48	56	52
C_{26}	55	24	10	22	23	29
C_{27}	130	110	19	110	69	130
C_{28}	55	19	ND	20	27	26
C_{29}	100	75	26	130	81	63
C_{30}	ND	ND	ND	ND	ND	ND
C_{31}	ND	ND	ND	ND	ND	ND

	DATE OF SAMPLE					
Aromatic Hydrocarbon	9/21	10/6	10/14	11/1	11/17	11/30
o-Xylene	ND	ND	ND	ND	ND	ND
Isopropylbenzene	ND	ND	ND	ND	ND	ND
n-Propylbenzene	ND	ND	ND	39	ND	ND
Indan	ND	ND	ND	ND	ND	ND
1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND	ND	ND
Naphthalene	ND	ND	3.3	13	ND	11
Benzothiophene[2]	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	ND	28	20	ND	72	20
1-Methylnaphthalene	ND	30	190	17	250	ND
Biphenyl	ND	ND	ND	ND	ND	14
2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND
2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND
Dibenzothiophene[2]	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	80	160	88	210	160
Anthracene	ND	ND	ND	ND	ND	ND
1-Methylphenanthrene	ND	ND	39	ND	ND	ND
Fluoranthene	ND	110	100	94	190	140
Pyrene	ND	87	45	78	17	100
Benz[*a*]anthracene	ND	ND	ND	ND	ND	ND
Chrysene	ND	57	ND	ND	ND	ND
Benzo[e]pyrene	ND	ND	ND	ND	ND	ND
Benzo[a]pyrene	ND	ND	ND	ND	17	ND
Perylene	ND	ND	ND	ND	ND	ND

[1] a branched alkane

[2] a sulfur-substituted aromatic hydrocarbon

ND=not detected

BEACH VARIABILITY STUDY

The objective of this study was to determine if differences in the data from different sites were greater than the differences for replicate samples from a single site; i.e., do the different sites contain measurably different levels of hydrocarbons? Duplicate samples of sediments were collected and analyzed during the spring and summer quarters from Cherry Point, March Point, Andrews Bay, Dungeness/Three Crabs, Tongue Point, and Baadah Point. Duplicate analyses of six spring samples were performed to determine differences in results from single composite samples.

Methods and Materials

The same methods and materials were used in this study as in the Hydrocarbon Baseline Study section.

Results and Discussion

The results of these analyses are summarized in Table 12 and the data for the individual hydrocarbons are reported in Appendix IV. The summarized data provide a mechanism to evaluate differences in replicates and differences between sites. The differences between duplicate analyses of a sample and between analyses of duplicate samples from a site were within expected results in most cases. The greatest differences between duplicates are in the data on sums of selected alkanes and sums of selected aromatic hydrocarbons. The duplicate analyses of the spring sample number 1 at Andrews Bay show the greatest difference, almost tenfold. We occasionally obtain such unexpected results from samples. Every step in the procedure is thoroughly checked and usually, as in this instance, no explanation is found for the discrepancy.

We used the ΣSelected Alkanes and ΣSelected Aromatic Hydrocarbons to rank the beaches according to hydrocarbon concentrations. The order is the same for both classes of compounds. The decreasing order with the respective values for alkanes and aromatics is as follows: 1. March Point (119,63); 2. Baadah Point (114,30); 3. Dungeness/Three Crabs (85,16); 4. Andrews Bay (78,11); 5. Cherry Point (42,10); and 6. Tongue Point (19,2).

This limited data set suggests that hydrocarbon concentrations can be used to indicate differences in petroleum compounds present at different sites, even in areas such as Northern Puget Sound where all sites have relatively small amounts of contamination.

TABLE 12. Data from Beach Variability Study.

	CHERRY PT.					MARCH PT.						ANDREWS BAY					
	SP			SU		SP				SU		SP				SU	
Sample Number	1A	1B	2A	1A	2A	1A	1B	2A	2B	1A	2A	1A	1B	2A	2B	1A	2A
Microgravimetric Analysis (μg/g dry)																	
Total sat'd hc's	2.6	2.8	3.1	4.6	4.1	7.6	8.8	7.1	5.4	6.2	10	11	5.0	8.2	6.2	2.7	3.3
Total unsat'd hc's	1.0	1.3	1.9	2.9	3.6	4.7	5.8	7.4	4.7	8.4	10	12	3.4	31	7.7	4.0	3.3
GC Analysis (ng/g dry)																	
ΣSelected Alkanes (nC_{12}-C_{20})	32	43	27	50	58	82	124	132	158	130	89	600	75	98	90	52	76
ΣSelected Aromatic hydrocarbons[1]	6	10	6	13	17	39	33	97	26	47	75	530	17	13	14	4	7
Sediment Analysis																	
Total Organic Carbon (%)	0.11		0.12	0.36	0.12	0.19		0.18		0.13	0.15	0.10		0.18		0.15	0.12
Sand/Mud Ratio	247		252	123	137	39.2		61.2		27.4	39.0	108		87.3		123	128

	DUNGENESS/3 CRABS					TONGUE PT.					BAADAH PT.			
	SP			SU		SP			SU		SP		SU	
Sample Number	1A	2A	2B	1A	2A	1A	2A	2B	1A	2A	1A	2A	1A	2A
Microgravimetric Analysis (μg/g dry)														
Total sat'd hc's	4.8	3.8	2.8	3.9	7.6	5.5	2.0	1.5	3.3	6.0	3.4	3.3	5.0	6.5
Total unsat'd hc's	18	8.9	2.8	3.4	9.0	11	3.6	2.5	5.3	8.4	8.9	2.5	4.3	2.4
GC Analysis (ng/g dry)														
ΣSelected Alkanes (nC_{12}-C_{20})	110	80	90	73	73	22	18	14	21	22	67	67	62	263
ΣSelected Aromatic hydrocarbons	17	11	16	18	18	2	0	0	3	3	41	20	27	32
Sediment Analysis														
Total Organic Carbon (%)	0.35	0.40		0.26	0.31	0.14	0.16		0.16	0.16	0.11	0.13	0.09	0.11
Sand/Mud Ratio	6.58	8.46		13.4	10.8	99.2	125		73.3	112	127	168	154	201

[1] selected aromatics are listed in text on page 18

Analyses of duplicate samples taken at one place are indicated by 1 and 2, e.g., 1A and 2A in the summer at Cherry Pt. Duplicate analyses of a single sample are indicated by A and B, e.g., 1A and 1B in the spring at Cherry Pt.

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APPENDIX I

Data archival information, the field data record sheet (figure I-1) and the key to codes (Table I-1) are included in the following pages.

Also included is the formatting sheet used in preparing data for transfer onto punch cards (figure I-2).

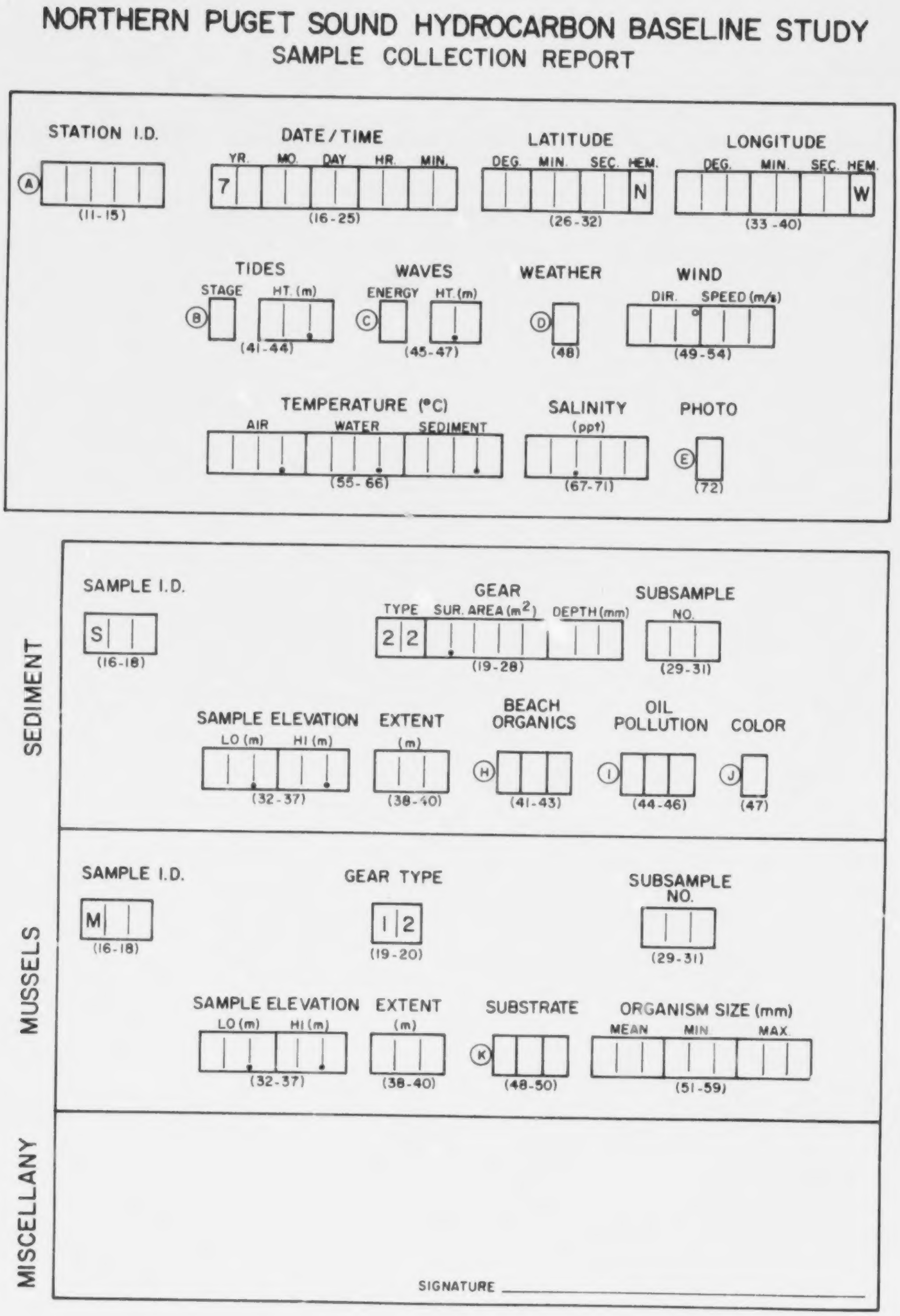
DATA LOCATION

All data from the quarterly studies and the Temporal Variability Study are available from NODC at:

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Oceanographic Data Center
Records Section
Washington, D.C. 20235

under the following titles:

Study	Title	Accession #	Track
Spring 77	HBSP77	77-0777	TR1893
Summer 77	HBSU77	78-0025	TR2716
Fall 77	HBFA77	78-0393	TR3070
Winter 77	HBWI77	78-0393	TR3071
Temporal Variability	77	78-0393	TR3072



NORTHERN PUGET SOUND HYDROCARBON BASELINE STUDY
SAMPLE COLLECTION REPORT

STATION I.D. Ⓐ (11-15)

DATE/TIME: YR. 7, MO., DAY, HR., MIN. (16-25)

LATITUDE: DEG., MIN., SEC., HEM. N (26-32)

LONGITUDE: DEG., MIN., SEC., HEM. W (33-40)

TIDES: Ⓑ STAGE, HT. (m) (41-44)

WAVES: Ⓒ ENERGY, HT. (m) (45-47)

WEATHER: Ⓓ (48)

WIND: DIR., SPEED (m/s) (49-54)

TEMPERATURE (°C): AIR, WATER, SEDIMENT (55-66)

SALINITY (ppt) (67-71)

PHOTO Ⓔ (72)

SEDIMENT

SAMPLE I.D. S (16-18)

GEAR: TYPE 2 2, SUR. AREA (m^2), DEPTH (mm) (19-28)

SUBSAMPLE NO. (29-31)

SAMPLE ELEVATION: LO (m), HI (m) (32-37)

EXTENT (m) (38-40)

BEACH ORGANICS Ⓗ (41-43)

OIL POLLUTION Ⓘ (44-46)

COLOR Ⓙ (47)

MUSSELS

SAMPLE I.D. M (16-18)

GEAR TYPE 1 2 (19-20)

SUBSAMPLE NO. (29-31)

SAMPLE ELEVATION: LO (m), HI (m) (32-37)

EXTENT (m) (38-40)

SUBSTRATE Ⓚ (48-50)

ORGANISM SIZE (mm): MEAN, MIN, MAX (51-59)

MISCELLANY

SIGNATURE ______________________

Figure I-1. Record sheet for collecting field data.

Table I-1. Key to codes used to record data on the field data record sheet.

ID Number	Station
1008	Birch Point
1012	Cherry Point
2014	Ediz Hook
2021	Dungeness Spit
2046	Cape George
2054	Pillar Point
2056	Baadah Point
2058	Deep Creek
2059	Crescent Bay/Tongue Point
2066	Keystone
2067	Deep Creek Beach
2068	Dungeness/Three Crabs
2069	Fort Casey
2070	N.A.S./Whidbey Is.
2071	Kydaka Point
3067	False Bay
3074	Andrews Bay
3107	Westcott Bay
4001	Sandy Point
4047	March Point
4053	Shannon Point
4092	Legoe Bay/Lummi Is.
4096	Alexander Beach

B: Tidal Stage Code

Blank = no information
1 = ebb
2 = ebb slack
3 = flood
4 = flood slack

D: Weather Code

Blank = no information
0 = clear (cloudless)
1 = partly cloudy (scattered or broken)
2 = completely overcast
3 = sandstorm, duststorm or blowing snow
4 = fog, thick dust, or haze
5 = drizzle
6 = rain
7 = snow, or rain and snow mixed
8 = shower
9 = thunderstorm

G: Gear Code

12 = hand collections
22 = surface coring device cylinder 2 cm deep x 5 cm across

C: Wave Energy/Beach Gradient Code

Blank = no information
1 = low wave energy; low beach gradient (slope $< 15\%$)
2 = low wave energy; moderate beach gradient (slope, 15-30%)
3 = low wave energy; high beach gradient (slope $> 30\%$)
4 = moderate wave energy; low beach gradient
5 = moderate wave energy; moderate beach gradient
6 = moderate wave energy; high beach gradient
7 = high wave energy; low beach gradient
8 = high wave energy; moderate beach gradient
9 = high wave energy; high beach gradient

E. Photo Code

Blank = no information
0 = no photos taken
1 = ground: black and white only
2 = ground: color only
3 = ground: black and white and color
4 = aerial: black and white only
5 = aerial: color only
6 = aerial: black and white and color
7 = aerial and ground: black and white only
8 = aerial and ground: color only
9 = aerial and ground: black and white and color

Table I-1. cont'd.

H: Beach Organics Code

Blank = no information
1 = chiefly shell fragments
2 = detritus, accumulated wood, sticks, and undecayed organics
3 = fibrous peat
4 = pulpy peat
5 = muck, completely decomposed organic materials
6 = eel grass
7 = kelp
8 = periphyton
9 = no organic materials evident

I: Oil Pollution Code

Blank = no information
0 = slick, indeterminable type
1 = slick, fish oils ("bait slick")
2 = slick, petroleum, thin
3 = slick, petroleum, thick
4 = frothy, petroleum, thin
5 = frothy, petroleum, thick
6 = tar, petroleum, thin
7 = tar, petroleum, thick
8 = other
9 = clean beach (no oil or carcasses observed)
A = some tarballs found
B = many tarballs found
C = light sheen on water
D = physical evidence of possible petroleum contamination (such as oil cans, gas tanks, oiled cardboard, etc.)
E = abnormal number of marine carcasses
F = abnormal number of bird carcasses
G = motorized boat within 50' of sampling site
H = other petrochemical contaminants (plastic, etc.)

J: Sediment Color Code

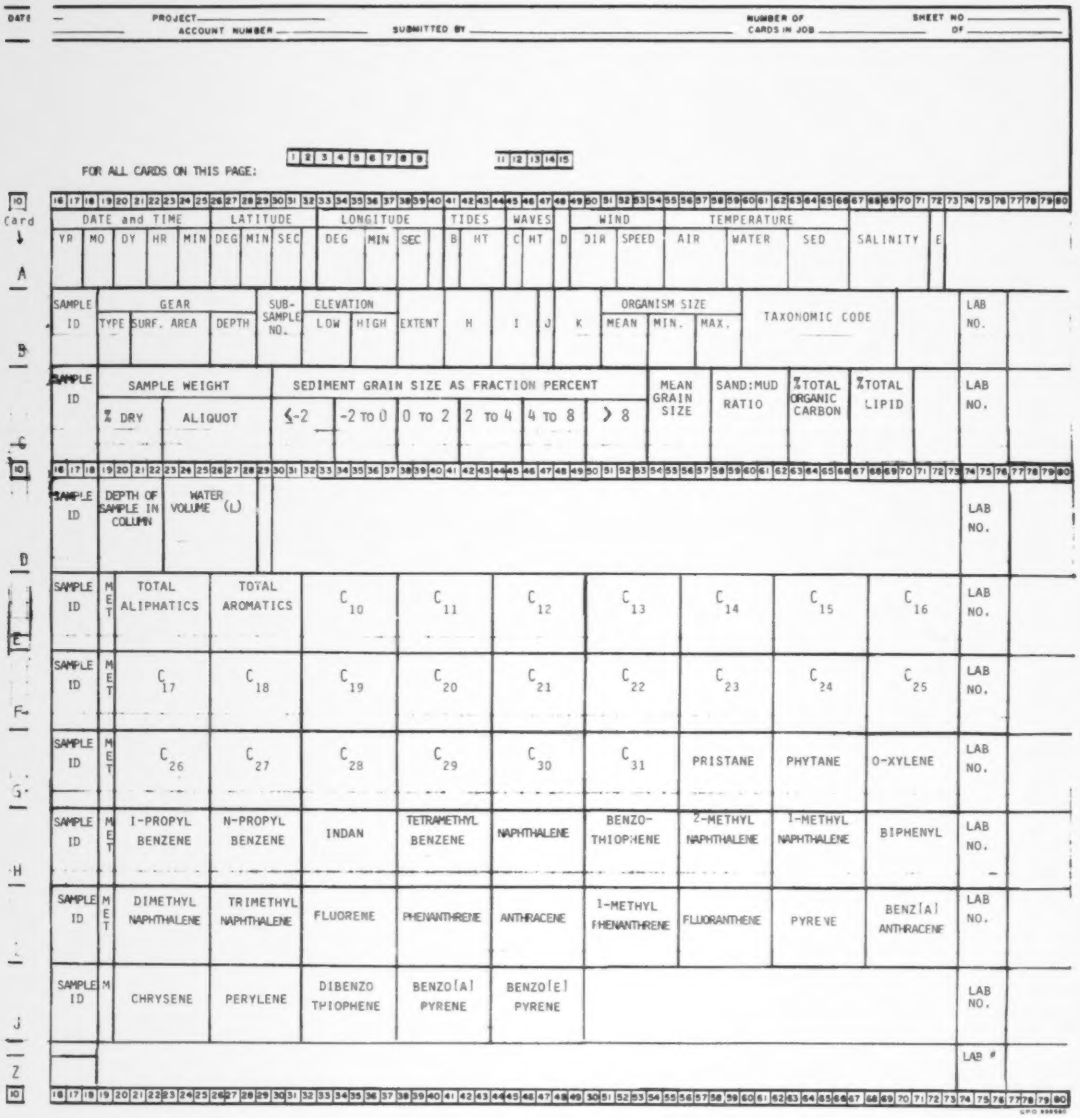
Blank = no information
1 = black
2 = black-gray
3 = white
4 = tan
5 = chocolate brown
6 = light brown
7 = yellow
8 = green
9 = red
A = gray
B = gray-brown

K: Substrate Composition

Blank = no information
0 = indeterminable
1 = mud
2 = sand
3 = shell
4 = small rocks
5 = medium rocks
6 = large rocks
7 = bed rock
8 = wood
9 = tide pool
A = dirt
B = scree
C = vegetation
D = clay
E = peat
F = gravel
G = boulders
H = combinations
J = talus
K = volcanic ash
l = concrete
m = wooden pilings
n = pebble
p = cobble

L: Method Code

1 = mussel analysis code (original)
2 = sediment analysis code (original)



DATE — PROJECT ____ ACCOUNT NUMBER ____ SUBMITTED BY ____ NUMBER OF CARDS IN JOB ____ SHEET NO ____ OF ____

FOR ALL CARDS ON THIS PAGE: 1 2 3 4 5 6 7 8 9 11 12 13 14 15

10 Card ↓

A

DATE and TIME					LATITUDE			LONGITUDE			TIDES		WAVES			WIND		TEMPERATURE				
YR	MO	DY	HR	MIN	DEG	MIN	SEC	DEG	MIN	SEC	B	HT	C	HT	D	DIR	SPEED	AIR	WATER	SED	SALINITY	E

B

SAMPLE ID	GEAR			SUB-SAMPLE NO.	ELEVATION		EXTENT	H	I	J	K	ORGANISM SIZE			TAXONOMIC CODE		LAB NO.
	TYPE	SURF. AREA	DEPTH		LOW	HIGH						MEAN	MIN.	MAX.			

C

SAMPLE ID	SAMPLE WEIGHT		SEDIMENT GRAIN SIZE AS FRACTION PERCENT						MEAN GRAIN SIZE	SAND:MUD RATIO	%TOTAL ORGANIC CARBON	%TOTAL LIPID		LAB NO.
	% DRY	ALIQUOT	≤-2	-2 TO 0	0 TO 2	2 TO 4	4 TO 8	> 8						

10

D

SAMPLE ID	DEPTH OF SAMPLE IN COLUMN	WATER VOLUME (L)		LAB NO.

E

SAMPLE ID	MET	TOTAL ALIPHATICS	TOTAL AROMATICS	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	LAB NO.

F

SAMPLE ID	MET	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	LAB NO.

G

SAMPLE ID	MET	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	PRISTANE	PHYTANE	O-XYLENE	LAB NO.

H

SAMPLE ID	MET	I-PROPYL BENZENE	N-PROPYL BENZENE	INDAN	TETRAMETHYL BENZENE	NAPHTHALENE	BENZO-THIOPHENE	2-METHYL NAPHTHALENE	1-METHYL NAPHTHALENE	BIPHENYL	LAB NO.

I

SAMPLE ID	MET	DIMETHYL NAPHTHALENE	TRIMETHYL NAPHTHALENE	FLUORENE	PHENANTHRENE	ANTHRACENE	1-METHYL PHENANTHRENE	FLUORANTHENE	PYRENE	BENZ[A] ANTHRACENE	LAB NO.

J

SAMPLE ID	M	CHRYSENE	PERYLENE	DIBENZO THIOPHENE	BENZO[A] PYRENE	BENZO[E] PYRENE		LAB NO.

Z

		LAB #

10

Figure I-2. Model of formatting sheet used to prepare data for transfer onto punch cards.

APPENDIX II

FIELD INFORMATION

List of Sites 48

Description of Sample Sites 49

Beach Characteristics 52

Maps and Photographs of Sites 55

List of Sites

1. Birch Point
2. Cherry Point
3. Sandy Point
4. March Point
5. Shannon Point
6. Alexander Beach
7. Fort Casey
8. Keystone Jetty
9. NAS Whidbey
10. False Bay
11. Andrews Bay
12. Westcott Bay
13. Legoe Bay
14. Cape George
15. Dungeness/Three Crabs
16. Dungeness Spit
17. Ediz Hook
18. Crescent Bay/Tongue Point
19. Deep Creek Beach
20. Deep Creek
21. Pillar Point
22. Kydaka Point
23. Baadah Point

DESCRIPTION OF SAMPLE SITES

Birch Point. Located in Birch Bay Village, Recreation Area Number Three, approximately five miles south of the Canadian Border. Forms upper boundary of Birch Bay proper. Cobble beach with intermittent patches of medium to fine sediment. Few large boulders. Tide pools with abundance of organisms. Low beach gradient. Abundance of *Mytilis edulis*. Private access.

Cherry Point. Variability site. Located near Ferndale, Washington, between Arco and Mobile refineries and adjacent to Intalco Aluminum Co. Access owned by Puget Sound Power and Light Co. Medium cobble beach with small intermittent patches of fine sediment. Non-sustaining colony of *Mytilis edulis*. Beach area exposed to Strait of Georgia. Large colonies of herring inhabit area during early summer. Public access.

Sandy Point. Confines upper end of Lummi Bay. Located approximately five miles from Interstate 5 between Bellingham and Ferndale. Extensive tide flats, bordered above the 0.6-m tidal level by medium sized cobble. Cobble contains relatively large colony of *Mytilis edulis*. Commercial Dungeness crab area. Exposed to surf action from Strait of Georgia. Private access.

March Point. Fidalgo Island. Located northeast side of March Point adjacent to boat launch area. Mussels attached to south side of boat launch jetty. Extensive tide flat area. Extensive population of water fowl. Variety and abundance of marine flora and fauna, particularly interstitial worms. Bounded by Padilla Bay on the east, Guemes Channel on the North and Fidalgo Bay on the West. Site of Shell and Texaco Oil Refineries. Public access.

Shannon Point. Fidalgo Island, west end of city of Anacortes. Located on Western Washington State University property adjacent to Washington State Ferry terminal property. Most of beach area covered with rocks, cobble to boulder size. Sediment sample area at west end of Univesity property, faces Guemes Channel, near County park. Not enough mussels to sustain a continuing sample. Private access.

Alexander Beach. Del Mar Development. Located just south of Skyline Marina (Anacortes) on Burrows Bay. Faces Rosario Strait. Vast area of fine sediment interspersed with bedrock. Adequate colony of mussels on rocks. Private access.

Fort Casey. Seattle Pacific University. Located on Whidbey Island adjacent to Keystone Ferry and Washington State Parks Dept. Property. Sample area in line with abandoned lighthouse. Coarse sediment in gravel area with few large rocks. Faces Admiralty Inlet. Private access.

Keystone Ferry Landing. Whidbey Island. Mussel site on South side of ferry landing jetty. Faces Admiralty Inlet. Ecology reserve, must have permission from Washington State Parks to sample. Public access.

U.S. Naval Air Station. Whidbey Island. Sizeable beaches of fine sediment. Good colonies of blue mussels. Exposed to turbulence from Rosario Strait. Sediment/mussel area located directly in front of Norwester Club. Private access. Permission from Base Commander through security officer.

False Bay. San Juan Island. Located west side, lower half of Island facing Haro Strait. Limited sediment at 0.0-m tidal level. Large areas of bedrock. Many tide pools, abundance of a variety of marine life. Mussel colonies very sparse. Private access. Permission from owners of Marvista Resort.

Andrews Bay. San Juan Island. Located upper half, west side of Island. Limited sediment coarse to fine at 0.0-m tidal level. No mussel crop. Greater than moderate beach gradient. Faces Haro strait. Private access. Permission from individual land owners on bay.

Westcott Bay. San Juan Island. Mussel site only. Located west side, upper half of island. Sheltered from Haro Strait by Henry Island. Mud flat area, produces variety of shellfish. Site of numerous University of Washington shellfish studies and aquaculture programs. Private access. Permission by Webb Camp caretaker.

Legoe Bay. Lummi Island. Alternate choice for Cherry Point mussel site. Located west side of island below Village Point, faces Strait of Georgia. Gravel beach. Good mussel colonies found on southern point of bay on bedrock and concrete blocks. Private access. Permission through Lummi Aquaculture School (formerly Hawleys resort).

Cape George. Access through the Cape George Colonies development; sampling site is 200 m north of the marina-picnic beach parking lot. Location is on the east entrance of Discovery Bay. Beach is of small to large cobble with some sand between rocks and limited sandy stretches at the 0.3-m level and above. Mussels were abundant within a 150-m length of beach. Private access.

Dungeness Town. Access by parking at 3 Crabs Restaurant and hiking to bench mark that was 300 m to the west. Sampling zone was 120 m due north of the bench mark. Beach was of 2 to 6-cm gravel interspersed with a sand-to-mud sediment. Sediment appeared to be highly organic. Mussels were wide-spread throughout the sampling area and were attached to the rocks or clusters of gravel. This area was protected from direct wave action from the Straits, but choppy conditions created heavy water-born sedimentation. Private access.

Dungeness Spit. Reached by parking at the Clallam County Dungeness Spit Park and hiking 0.9 km to the beach. USCGS bench mark was available at the end of the trail. The sampling area was 50 m northwest of the bench mark. The beach was always subject to a heavy wash from the Strait. Mussels were not available anywhere on the outer spit. Access subject to permission from the Clallam County Parks authorities.

Ediz Hook. Sampling area was reached by passing onto U.S. Coast Guard Station on Ediz Hook, proceeding past last hangar to a point 200 m east of the wooden seaplane ramp. Bench mark was the 1-m square concrete drain pipe extending onto the beach. Beach was of 5 to 20-cm cobble above the 0.0-m tidal level, except for a limited sand area to the east of the bench mark that served as the sediment collection area. Mussels were abundant through the cobble near the 0.6-m tidal level. Although the area was protected from direct waves from the Straits, the area was subject to surge waves and waves from the heavy shipping activity in the area. Access subject to permission from the Coast Guard.

Tongue Point. Access by parking in the Clallam County Park parking lot at the mouth of the Lyre River and hiking 400 m to the sampling area. Beach is of sand except for bedrock areas at shore edge and the prominent 25-m high pinnacle and bedrock projection adjacent to the pinnacle. Sediment was collected due south of the pinnacle and mussels were taken at the base of the pinnacle. The sampling area is semi-protected from the direct waves of the Strait. Sampling of sediment and mussels subject to permission from the Clallam County Parks authorities.

Deep Creek Beach. Access from pull-off zone of Highway 101 that is one kilometer east of Deep Creek. Beach of gravel above the +0.6-m level and of continuous sand beyond with boulders interspersed. Sediment only. Public access.

Deep Creek. Access through unregulated public camping area along the east bank of Deep Creek. Beach of large cobble through entire area. Mussels available in restricted area near the +0.6-m tidal level adjacent the Deep Creek bed. Mussels are subject to fresh water wash from Deep Creek. Public access.

Pillar Point. Sampling site was reached by proceeding over Merrill- Ring Tree Farm road that follows the Pysht River and ends at the inner (southeast) beach of Pillar Point. The beach is entirely of sand while the point is of bedrock. Sediment reference mark was the southmost, low (0.4 m high) large rock at the +0.6-m level. Mussel samples were taken from the isolated boulders due south of Pillar Point. Access subject to permission from Merrill-Ring.

Kydaka Point. Access through the Crown-Zellerbach public camping area at the mouth of the Hoko River. Sediment bench mark is at the tip of the vegetated area that separates the Hoko River from the sea. Beach is entirely of sand except for the bedrock formation at the mouth of the Hoko River. Sediment was sampled north of the bench mark and 200 m west of the bedrock area; mussels were sampled at the +0.3 to 0.9-m tidal level of the bedrock. The entire area was subject to heavy wash from the Strait during storms. The mussel area was subjected to brackish water from the Hoko River. Access subject to permission from Crown-Zellerbach.

Baadah Point. Access to sampling site (while heading westbound on State Highway 9A) by taking the first right turn past the Bureau of Indian Affairs office and proceeding to Baadah Point and parking at the small creek. Sediment was taken between the creek and the bedrock area of Baadah Point (an area which was entirely sand). Mussels were abundant between the +0.6 to 1.0-m levels of the bedrock area of Baadah Point. The sampling area was sheltered from direct waves from the Straits by Waadah Island. Public access.

Table II-1. Location and characteristics of the 23 sampling sites ranging from Baadah Point at west end of the Strait of Juan de Fuca to Birch Bay at the south end of the Strait of Georgia

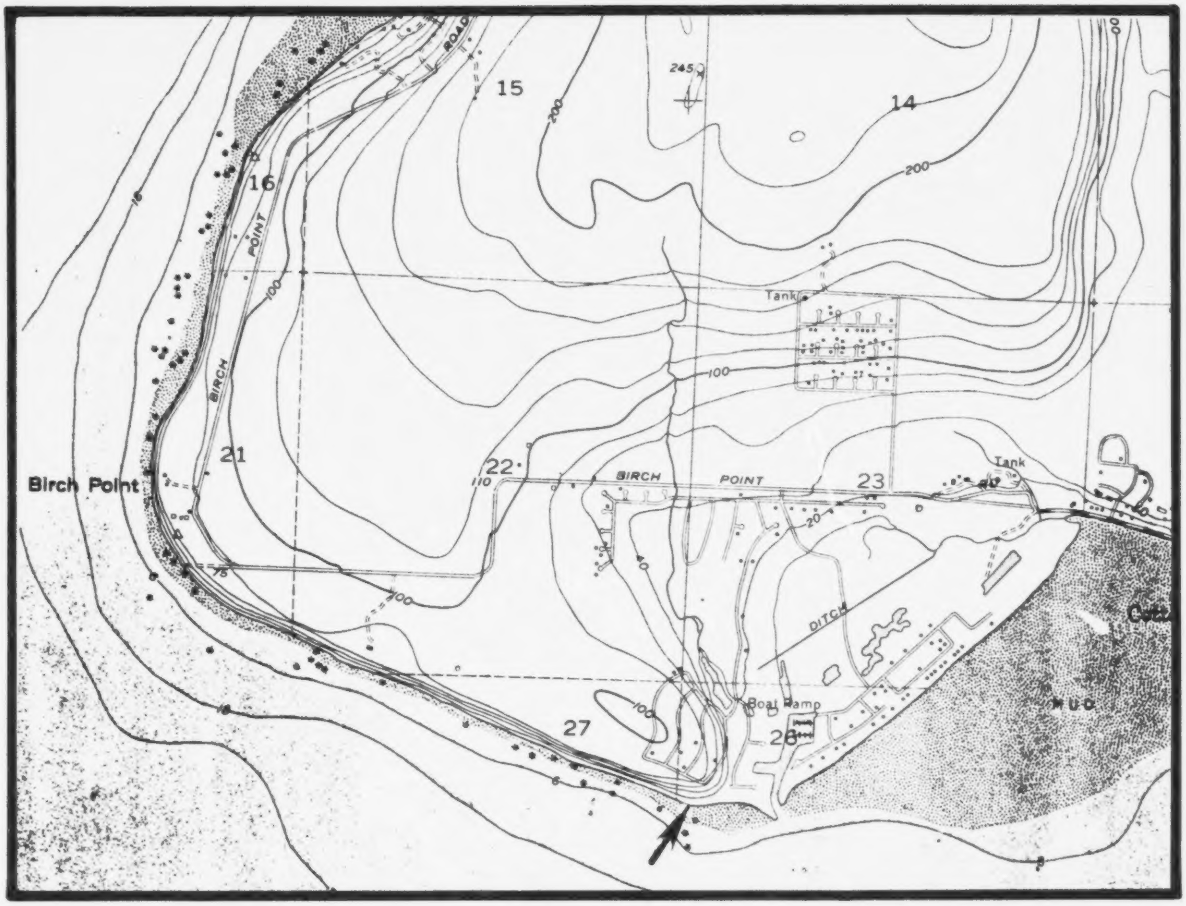
Site Latitude "N" Longitude "W"	Beach		Exposure to waves	Substrate M=mussels S=sediment
	Gradient	Substrate		
Baadah Point 48°22'25" 124°35'23"	Moderate, 5-15°	Grey well washed sand with solid bedrock on the point.	Protected from direct ocean waves but subject to heavy surge.	M-S
Kydaka Point 48°17'45" 124°21'40"	Moderate, 10-15°	Grey well washed sand with solid bedrock on the point.	Directly exposed to frequent winter storms causing heavy wave action. Hoko River washes over mussel area on point.	M-S
Pillar Point 48°12'48" 124°06'10"	Low, <5°	Grey washed sand interspersed with bedrock outcroppings.	Protected from direct waves from the Strait for all wind directions except north and east.	M-S
Deep Creek 48°10'35" 124°01'20"	Low, <5°	Continuous cobble of a 10-30 cm greatest dimension.	Directly exposed to surf from the Strait. Deep Creek washes over mussel collection area.	M
Deep Creek Beach 48°10'20" 124°01'00"	Moderate 5-15°, Initial 50 m; then low-5°	Gravel beach graduates to grey washed sand at the +0.6-m level. Patches of cobble and large rocks at lower elevations.	Negligible protection from waves from Strait.	S
Tongue Point 48°09'54" 123°42'18"	Low, <5°	Grey washed sand with bedrock outcroppings and continuous bedrock on point.	Receives surge of waves from Strait with modest protection. Lyre Creek empties 100 m from sample sites.	M-S
Ediz Hook 48°08'22" 123°24'18"	Moderate, 5-15°	Cobble to gravel with a few patches of sand.	Protected from direct waves of Strait and is subject to waves from shipping activity.	M-S

Table II-1 (cont'd)

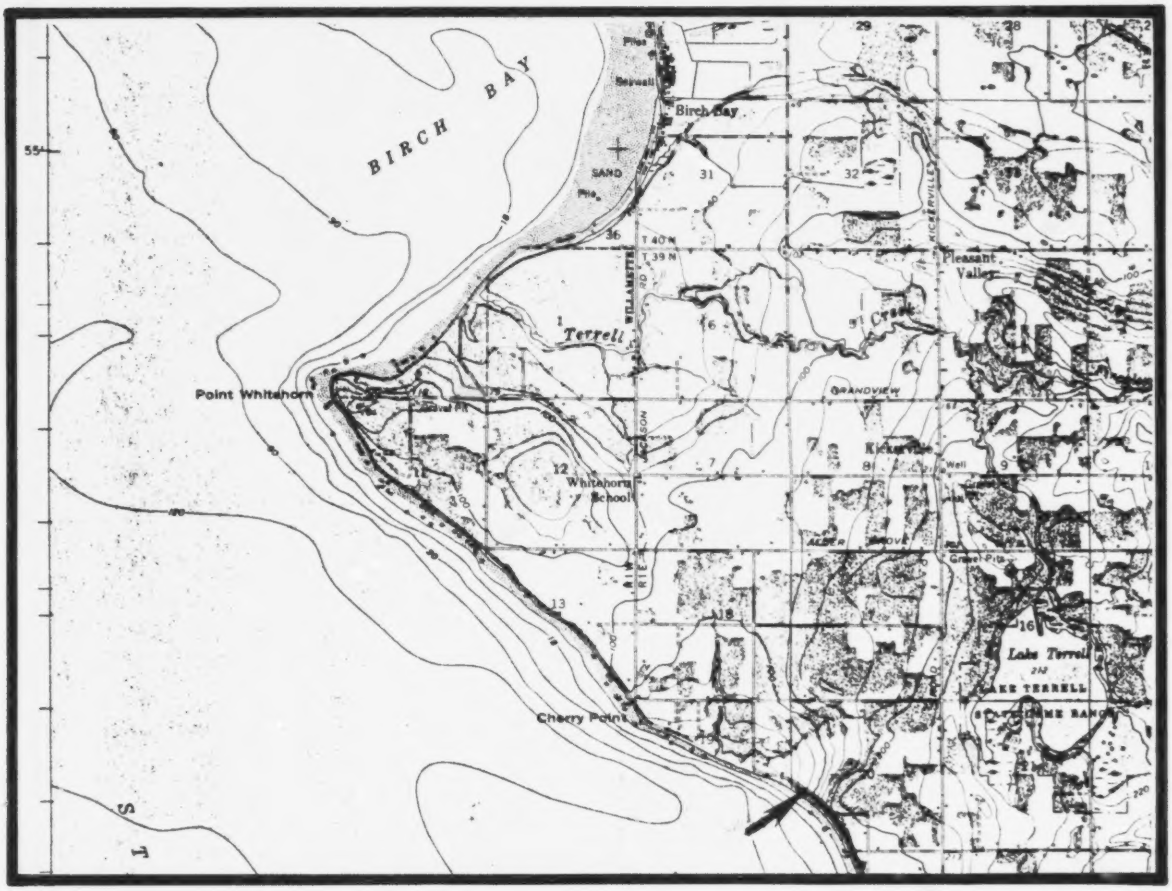
Dungeness Spit 48°08'45" 123°11'12"	Steep, 15°	Course sand subject to heavy wash almost constantly.	Subject to constant heavy wash from Strait and tidal action.	S
Dungeness/ Three Crabs 48°09'10" 123°07'15"	Low, <5°	Fine sand to occasional pebbles. Considerable infauna and organic material incorporated in sediment.	Subject to wind generated waves of general modest height. No heavy surge wave action.	M-S
Cape George 48°06'15" 122°53'04"	Moderate, 10-15°	Large cobble, 10 to 40 cm in greatest dimension, some locations interspersed with sand patches.	Occasionally subject to moderate wave action; heavy surge never observed.	M-S
Whidby Island, Keystone 48°09'21" 122°40'15"	Steep, 20°	Beach is of heavy gravel; mussel collection area is heavy rock riprap for jetty.	Wave action sometimes heavy. Tidal currents are consistently extremely swift.	M
Whidby Island, Fort Casey 48°09'45" 122°47'55"	Moderate, 10-15°	Upper elevation is of gravel to cobble; at +0.6 m substrate is of sand with boulders.	Wave action often heavy. Tidal currents are usually swift but less swift than at Keystone.	S
Whidby Island, Naval Air Station 48°20'32" 122°41'07"	Moderate, 10-15°	Upper elevation is of gravel to cobble; at +0.6 m substrate is of sand with 2-m boulders.	Wave action often heavy.	M-S
Alexander Beach 48°28'36" 122°39'38"	Low, <5°	Fine, grey sand from 1 m to lower low water. Above 1 m bedrock and large boulders.	Moderate wave action, sheltered from Rosario Strait by Burrows Is. and Allen Is.	M-S
Shannon Point 48°30'17" 122°41'17"	Moderate, 10-15°	Fine, grey sand at 0.6-m level. Sediment area surrounded by medium to large rocks.	Faces Guemes Channel, subject to moderate to high wind and wave action.	M-S

Table II-1 (cont'd)

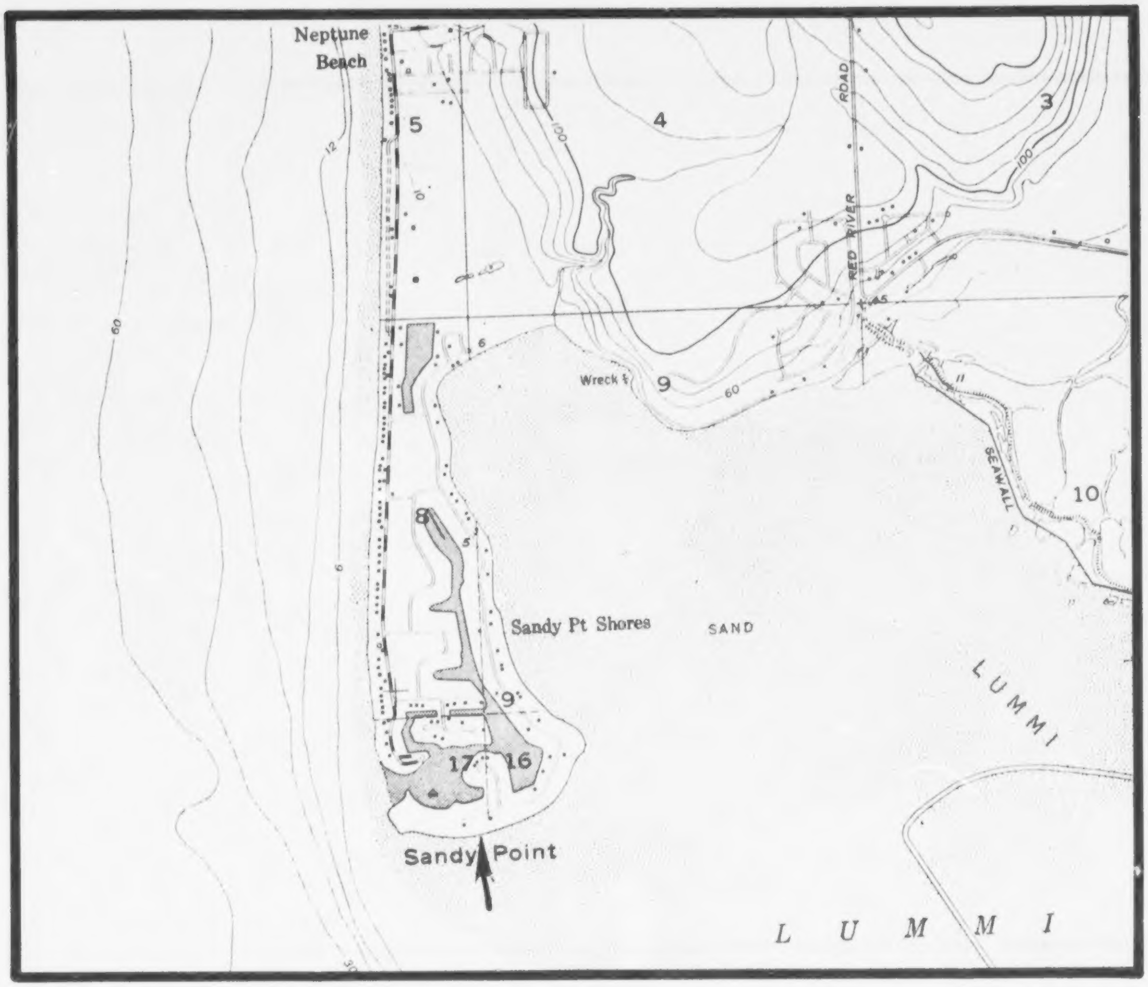
March Point 48°29'54" 122°33'41"	Moderate, 10°	Fine to coarse sand to gravel. Noticeable seasonal change in structure and algal composition. Small boulders, concrete blocks.	Moderate to low wind and wave action from Padilla Bay and Guemes Channel.	M-S
Sandy Point 48°47'10" 122°42'20"	Low, <5°	Extensive mud flats. Upper beach small cobble, with extensive mussel colony.	Moderate to heavy wave and wind action from Strait of Georgia.	M-S
Cherry Point 48°51'20" 122°43'45"	Moderate, 5-10°	Patches of fin sand interspersed with extensive cobble on lower beach. Upper beach sand and gravel.	Faces Strait of Georgia. Moderate to heavy wind and wave action.	S
Birch Point 48°55'55" 122°47'24"	Low, 5°	Fine to coarse sand interspersed with medium cobble. Large mussel colony, variety of fauna.	Forms upper boundary of Birch Bay, faces turbulence from Strait of Georgia.	M-S
Westcott Bay 48°35'50" 123°08'27"	Low, 5°	Mud flat area, variety of shellfish and other fauna.	Confluent with Garrison Bay. Low wave action. Sheltered from Haro Strait by Henry Is. NW corner of San Juan Is.	M
Andrews Bay 48°32'50" 123°09'23"	Moderate, 10-15°	Small patches of fine sand interspersed with coarse sand and gravel at 0.0 m. Beach area confined by bedrock.	Subject to direct wind and wave action from Haro Strait. Upper Middle San Juan Is.	S
False Bay 48°28'53" 123°03'54"	Moderate, 10-15°	Fine sand at 0.0.-m tidal level. Large areas of bedrock. Wide variety of fauna.	Moderate wave action, sheltered from Haro Strait.	S
Legoe Bay 48°42'52" 122°41'54"	Moderate, 5-10°	Gravel beach, areas of bedrock and concrete block. Good mussel colonies.	Moderate wind and wave action, faces Strait of Georgia.	M


ROAD
15
245
200
14
16
POINT
BIRCH
100
Tank
100
21
Birch Point
22
110
BIRCH
POINT
23
Tank
20
40
75
100
DITCH
Boat Ramp
27
28
100
MUD
Cott
10
6

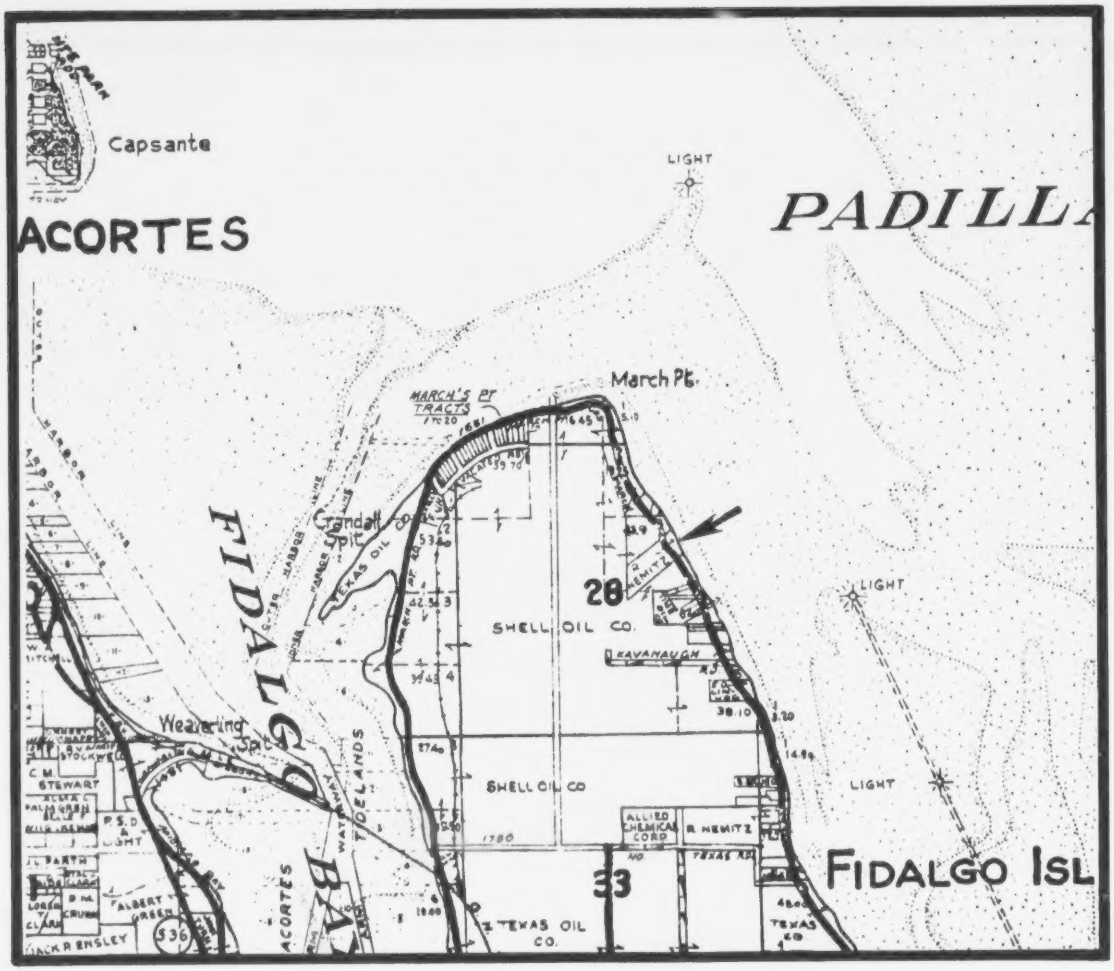
1. Birch Point: Strait of Georgia.


BIRCH BAY
Birch Bay
SAND
Point Whitehorn
Terrell
T 40 N
T 39 N
Pleasant Valley
GRANDVIEW
Kickerville
Whitehorn School
Cherry Point
Lake Terrell
LAKE TERRELL
Gravel Pits
55

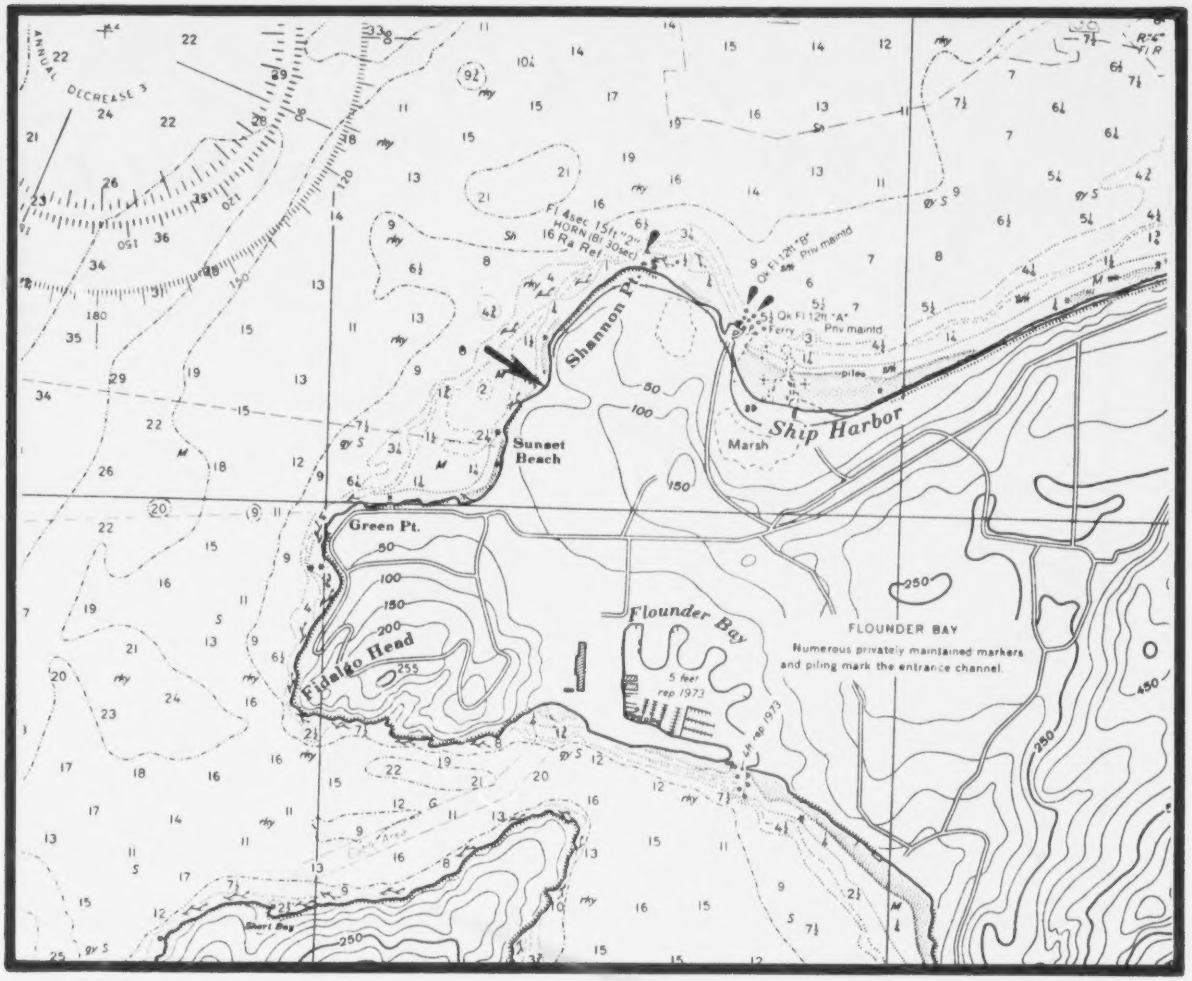
2. Cherry Point: Strait of Georgia.


Neptune Beach
5
4
3
ROAD
RED RIVER
100
60
12
Wreck
9
SEAWALL
10
8
Sandy Pt Shores
SAND
LUMMI
17
16
Sandy Point
L U M M I
30

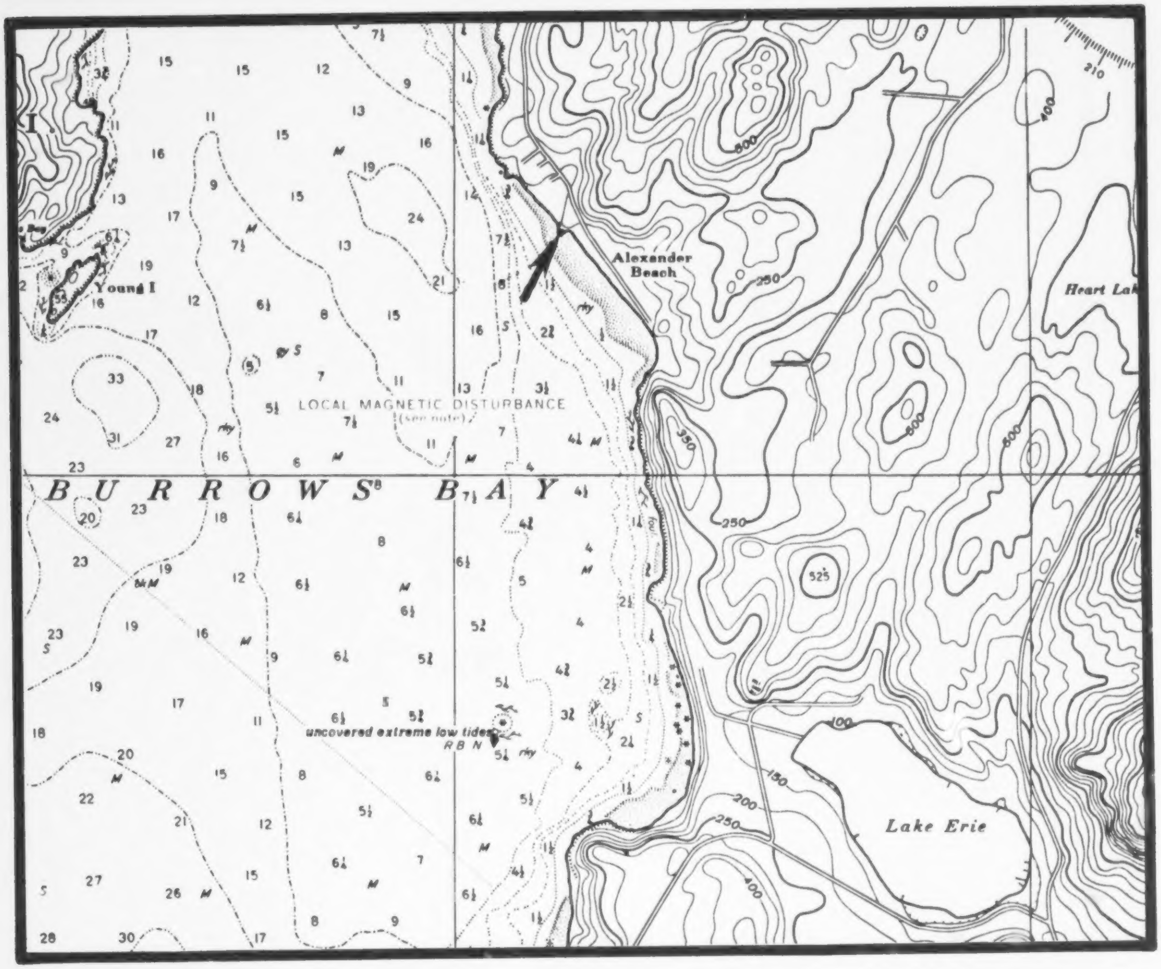
3. Sandy Point: Strait of Georgia.


Capsante
ACORTES
LIGHT
PADILL
March Pt.
MARCH'S PT TRACTS
Crandall Spit
FIDALGO
28
SHELL OIL CO.
KAVANAUGH
Weaverling Spit
TEXAS OIL
TIDELANDS
WATERWAY
SHELL OIL CO
ALLIED CHEMICAL CORP
R. NEMITZ
LIGHT
FIDALGO ISL
33
BAY
ACORTES
TEXAS OIL CO.
TEXAS CO
C. M. STEWART
P.S.D. & LIGHT
ALBERT GREEN
JACK R ENSLEY
536

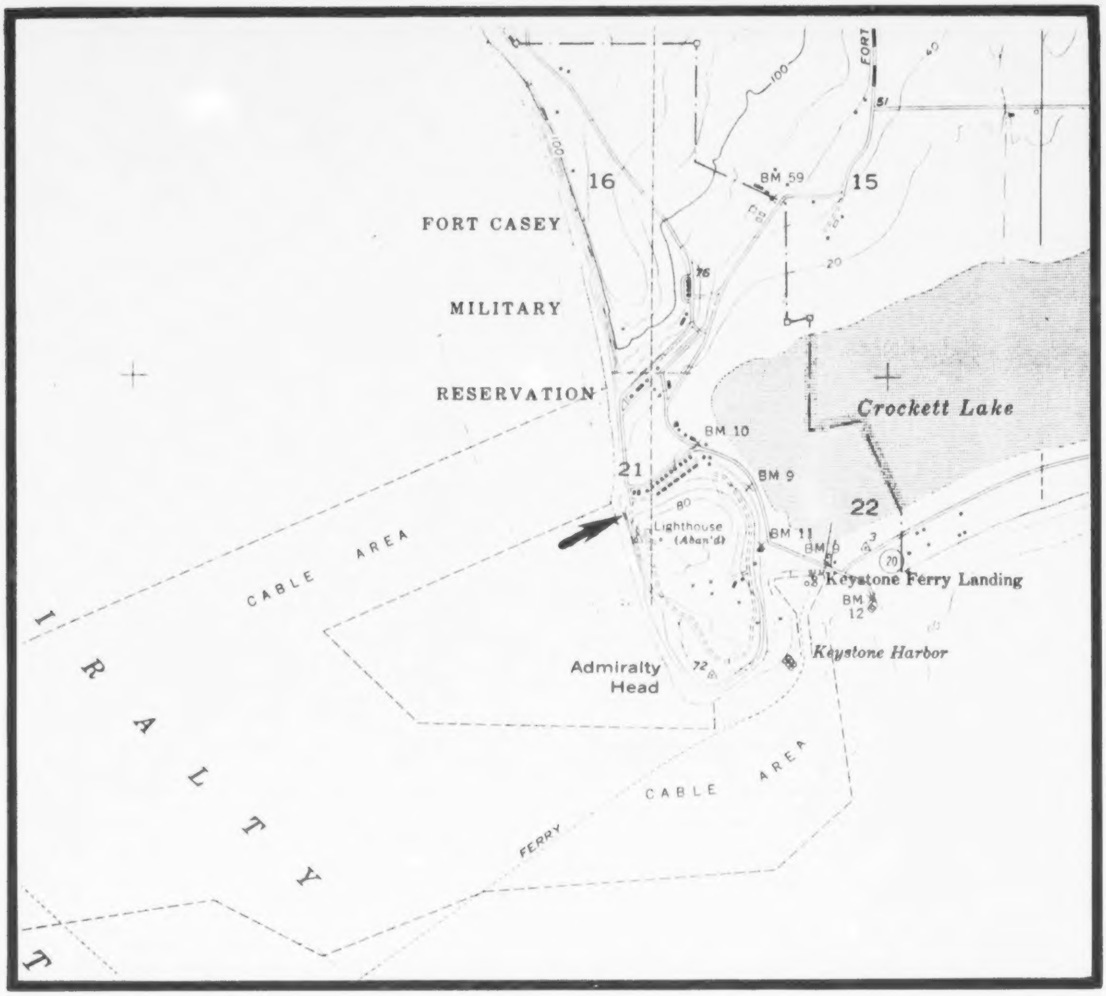
4. March Point: Guemes Channel, Padilla Bay.


Shannon Pt.
Ship Harbor
Sunset Beach
Green Pt.
Fidalgo Head
Flounder Bay
FLOUNDER BAY
Numerous privately maintained markers and piling mark the entrance channel.
Marsh
Ferry
Short Bay
ANNUAL DECREASE 3'
5 feet rep 1973
Fl 4sec 15ft "2" HORN (Bl 30sec) 16 Ra Ref
Qk Fl 12ft "B" Priv maintd
Qk Fl 12ft "A" Priv maintd

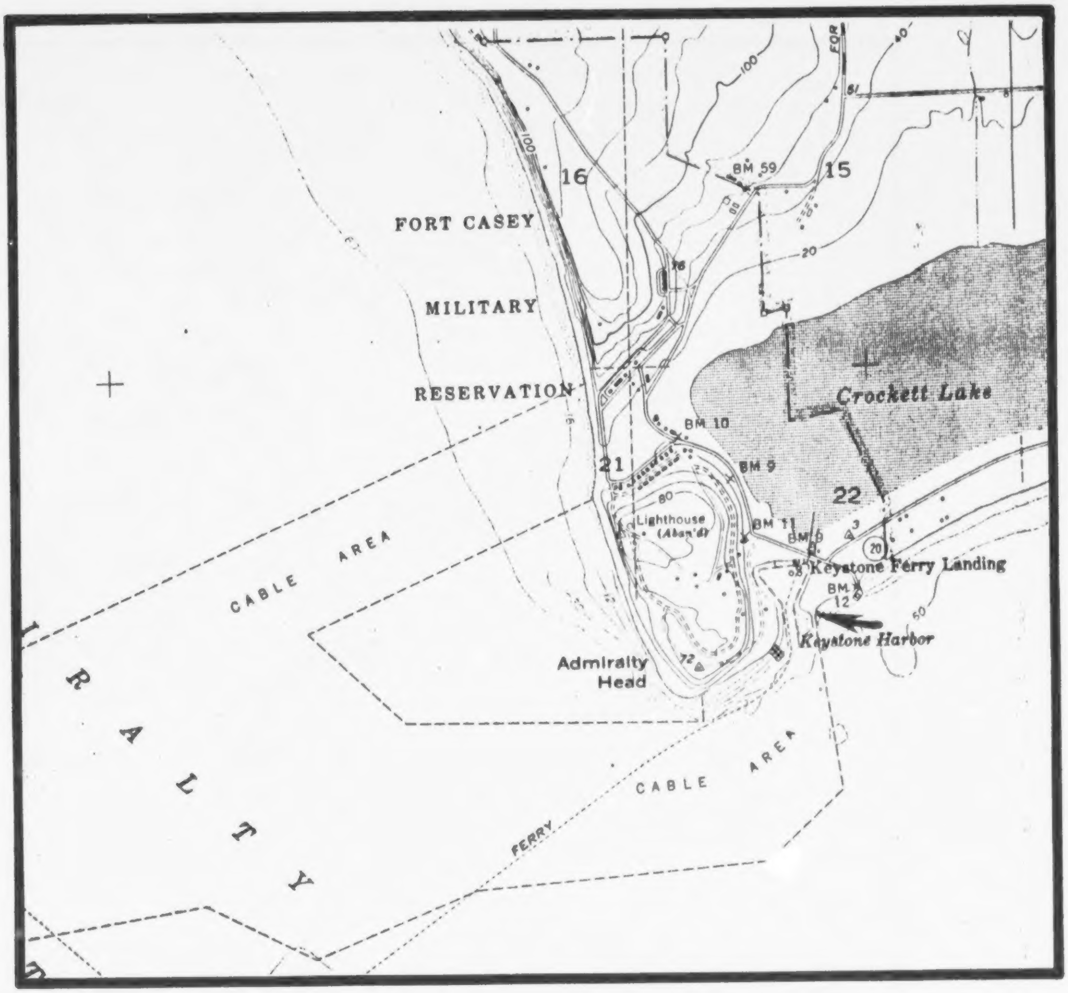
5. Shannon Point: Rosario Strait, Guemes Channel.


Alexander Beach
BURROWS BAY
Young I
LOCAL MAGNETIC DISTURBANCE
(see note)
uncovered extreme low tide
RBN
Lake Erie
Heart Lak
525
250
350
600
400
200
150
100

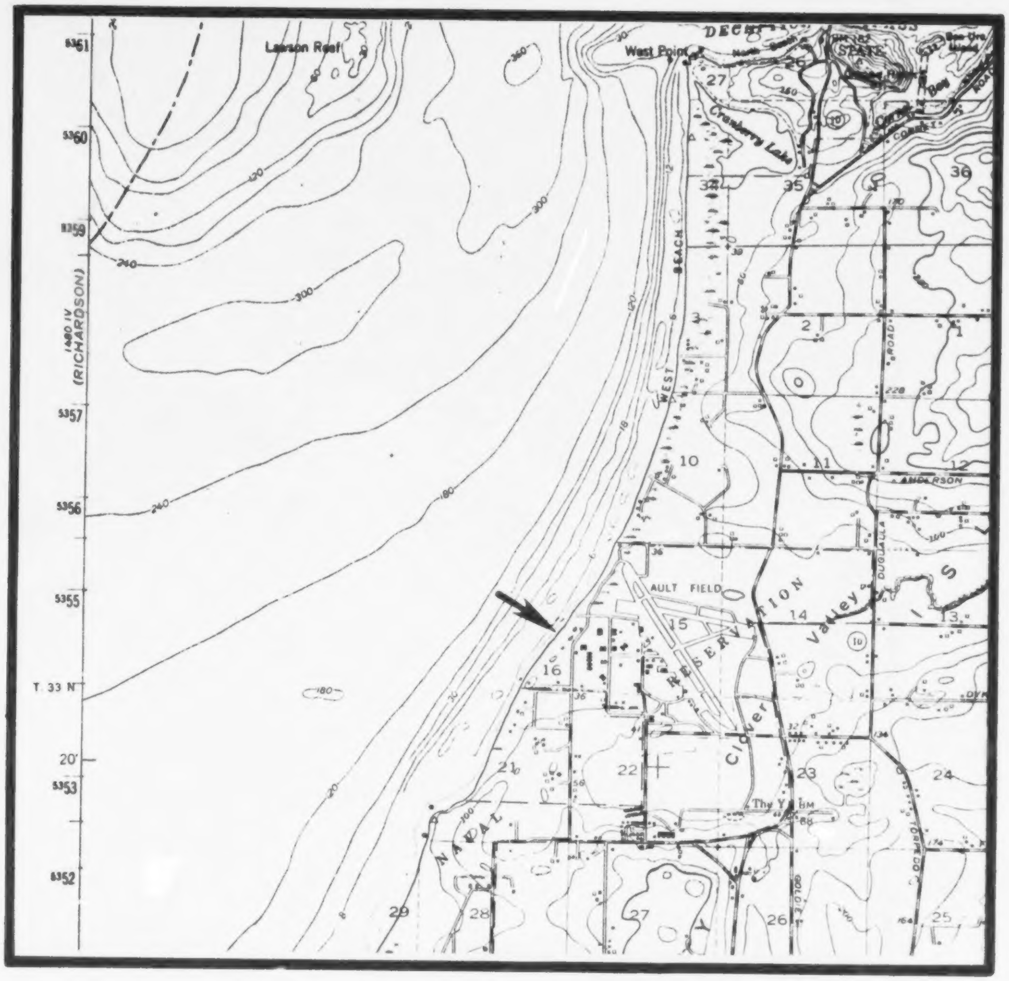
6. Alexander Beach: Rosario Strait.


FORT CASEY
MILITARY
RESERVATION
16
15
21
22
BM 59
BM 10
BM 9
BM 11
BM 12
Crockett Lake
Lighthouse (Aban'd)
Keystone Ferry Landing
Keystone Harbor
Admiralty Head
CABLE AREA
FERRY CABLE AREA
IRALTY
T
FORT
100
20
80
72
20

7. Fort Casey: Rosario Strait, Admiralty Inlet.


FORT CASEY
MILITARY
RESERVATION
16
15
21
22
100
20
BM 59
BM 10
BM 9
BM 11
BM 12
80
Lighthouse (Aban'd)
Crockett Lake
Keystone Ferry Landing
20
Keystone Harbor
Admiralty Head
72
CABLE AREA
CABLE AREA
FERRY
RALTY

8. Keystone Ferry: Rosario Strait, Admiralty Inlet.


Lawson Reef
West Point
DECEPTION
STATE
Cranberry Lake
1480 IV
(RICHARDSON)
WEST BEACH
AULT FIELD
NAVAL RESERVATION
Clover Valley
ANDERSON
DUGUALLA
The Y
T. 33 N
20'
5361
5360
5359
5357
5356
5355
5353
5352
240
300
180
120
27
34
35
36
3
2
1
10
11
12
15
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22
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23
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29
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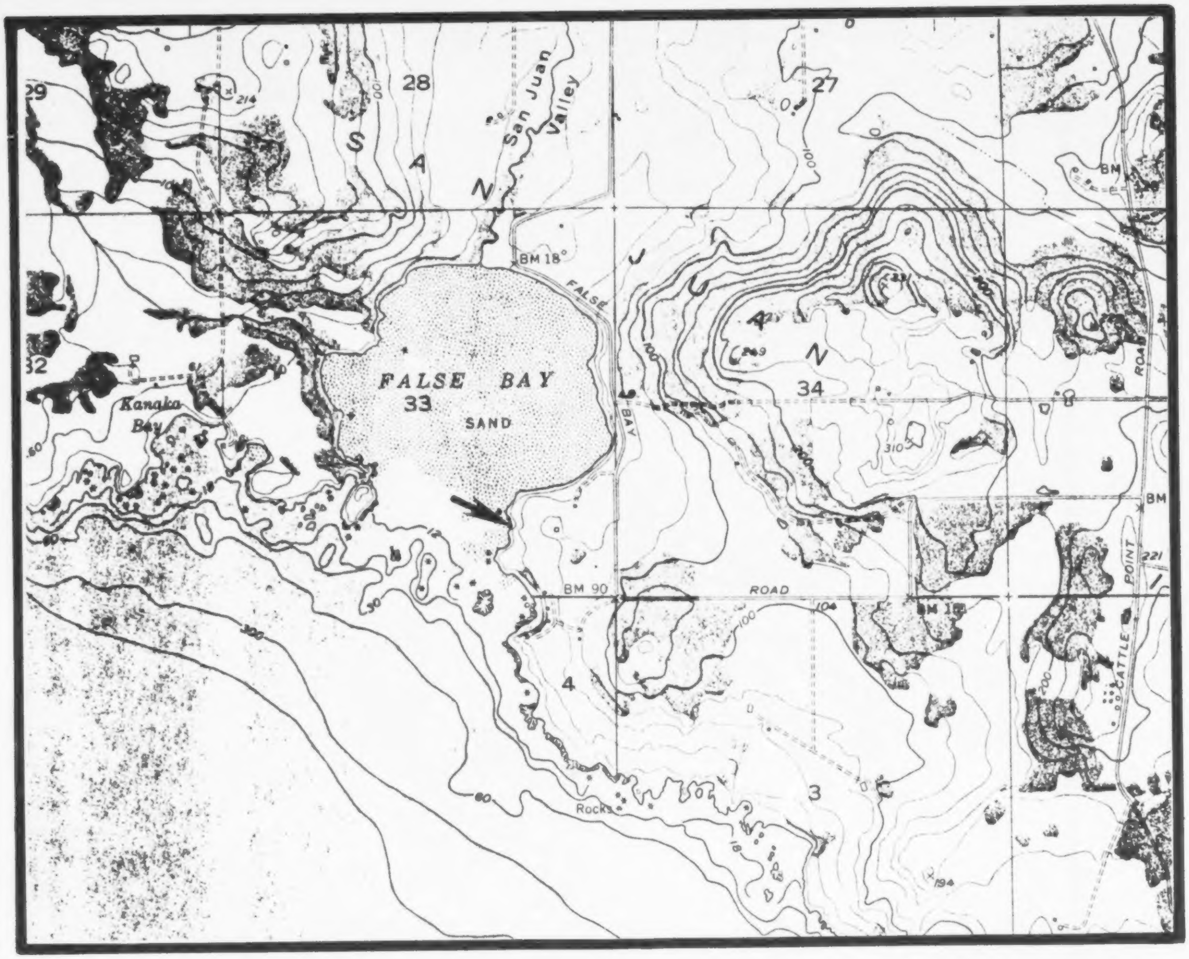
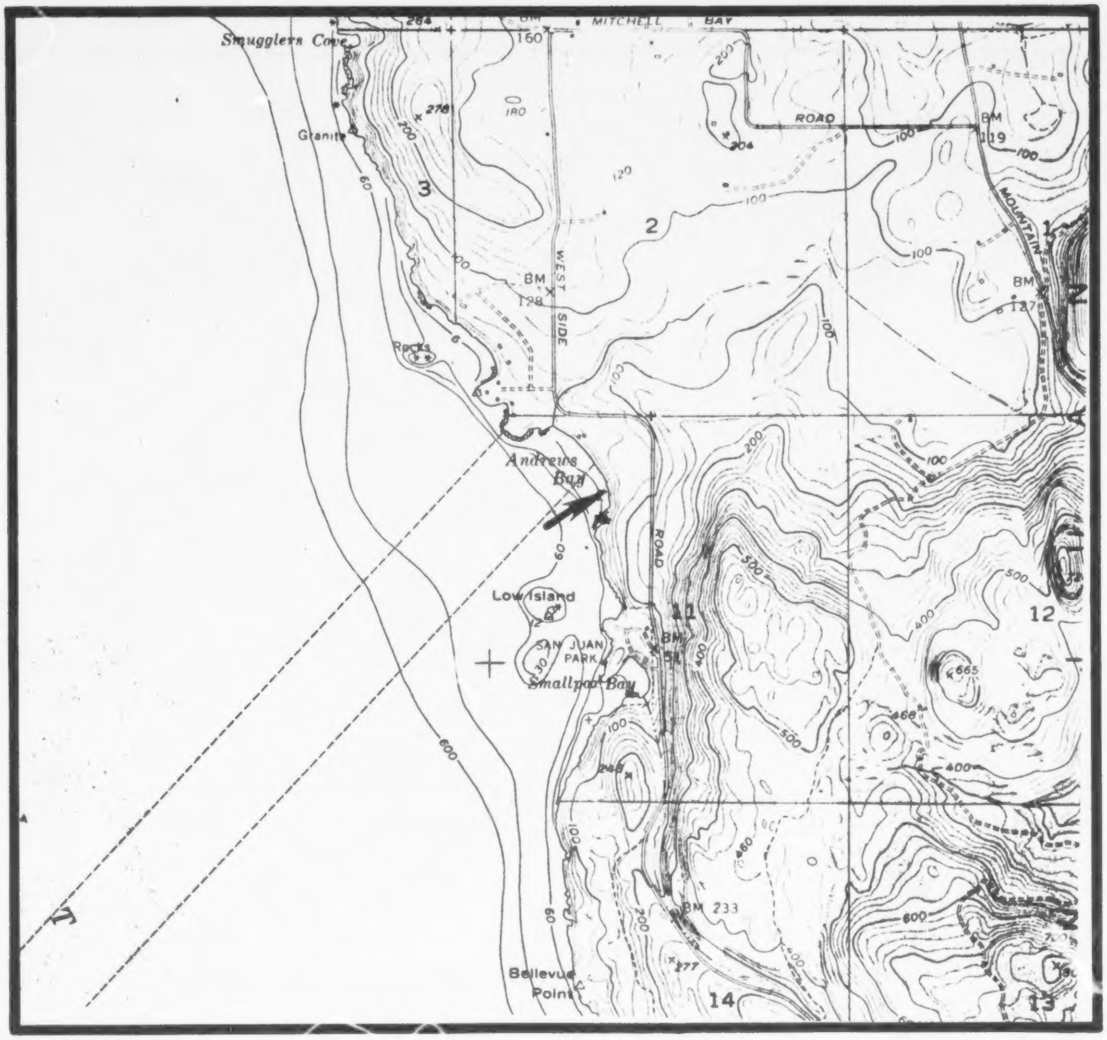
27
26
25

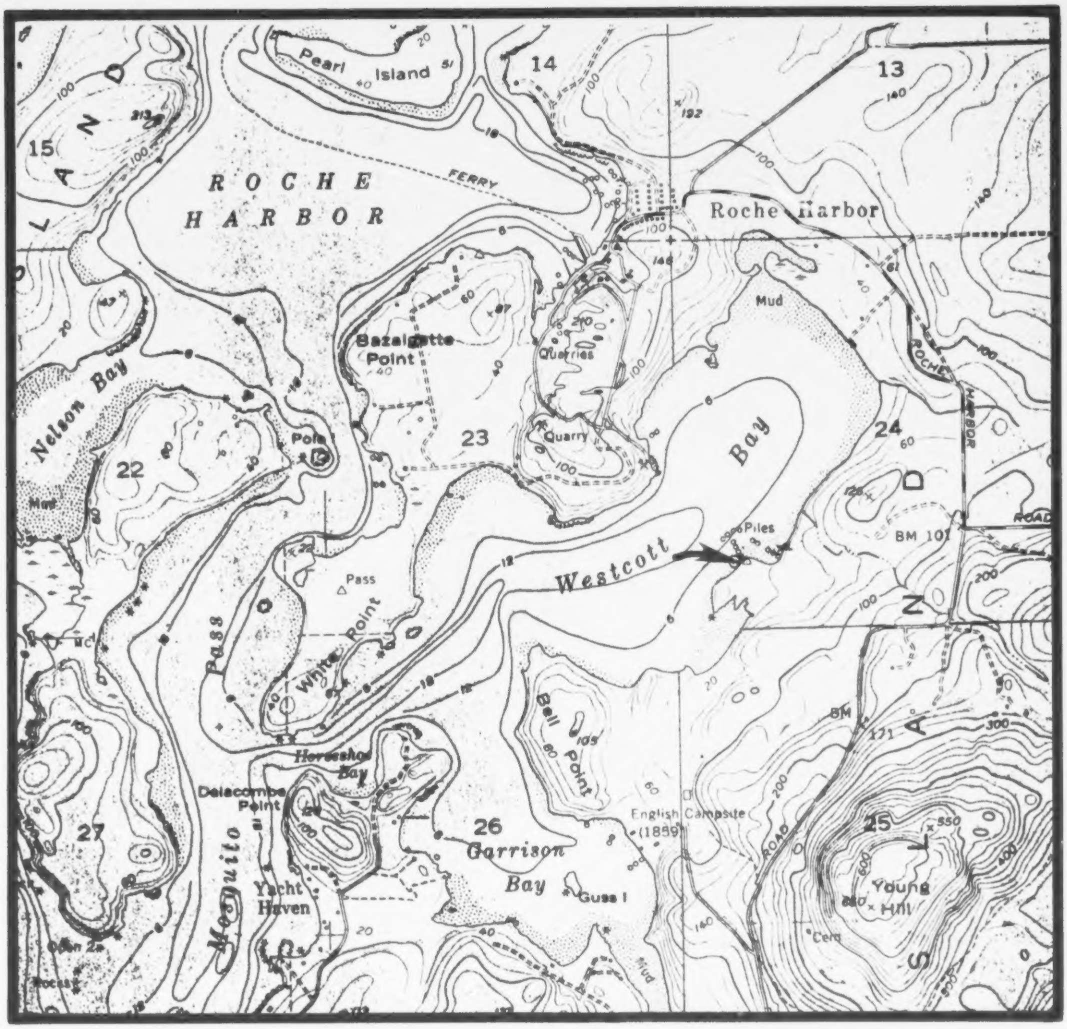
9. Naval Air Station, Whidbey Island: Rosario Strait.


29
28
27
S A N J U A N
San Juan Valley
BM 18°
FALSE BAY ROAD
FALSE BAY
33
SAND
34
32
Kanaka Bay
BM
BM 90
ROAD
CATTLE POINT ROAD
221
310
4
3
Rocks
60
300

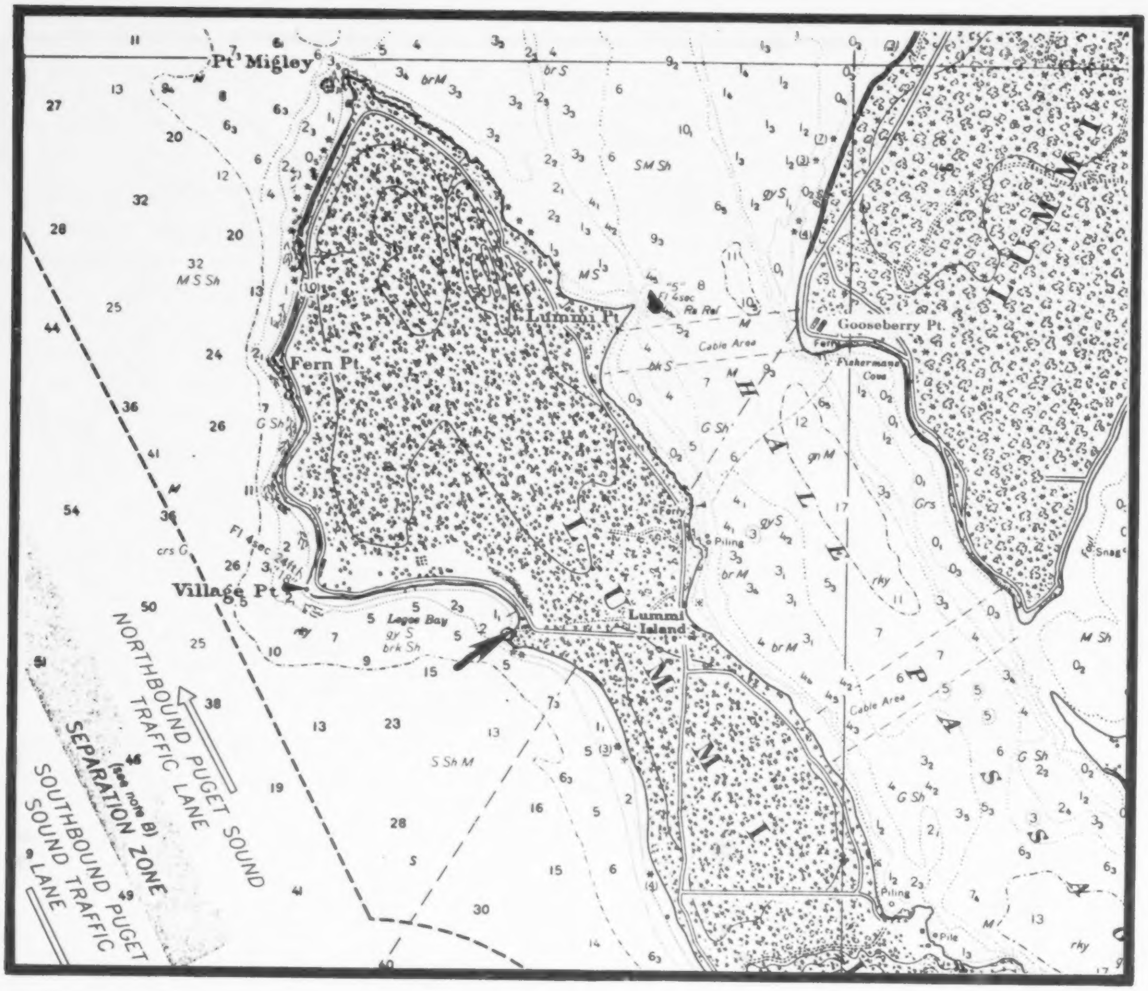
10. False Bay: Haro Strait.


Smugglers Cove
MITCHELL BAY
284
BM 160
Granite
276
200
180
3
2
120
100
ROAD
204
BM 119
MOUNTAIN
BM 127
BM 128
WEST SIDE
Rocks
Andrews Bay
ROAD
Low Island
SAN JUAN PARK
Smallpox Bay
11
BM 51
500
400
12
665
600
BM 233
277
Bellevue Point
14
13

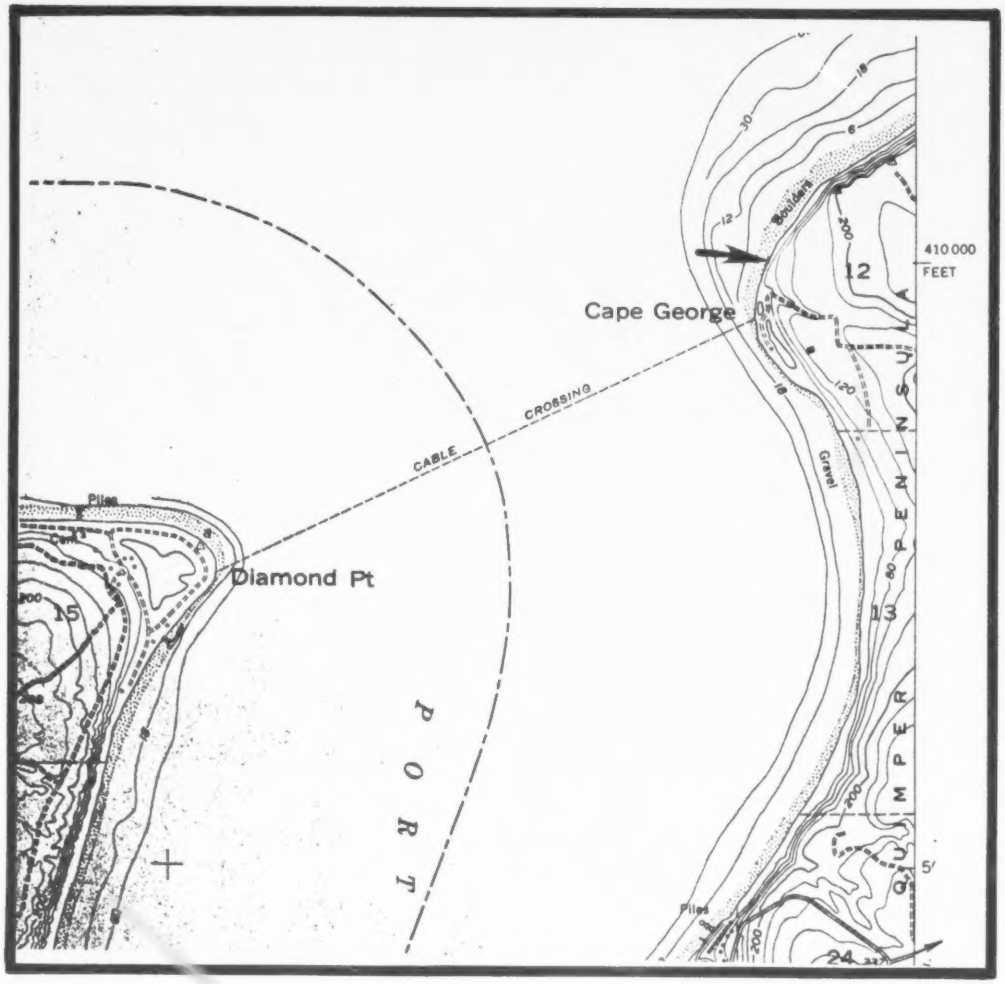
11. Andrews Bay: Haro Strait.


Pearl Island
14
13
15
ROCHE HARBOR
FERRY
Roche Harbor
Mud
Bazalgette Point
Quarries
Nelson Bay
Pole
22
23
Quarry
24
Bay
Westcott
Piles
BM 101
ROAD
ROCHE HARBOR
Pass
Pass
White Point
Bell Point
Horseshoe Bay
Delacombe Point
26
Garrison
Bay
Guss I
English Campsite (1859)
25
Young Hill
27
Yacht Haven
Mosquito
Mud
ROAD

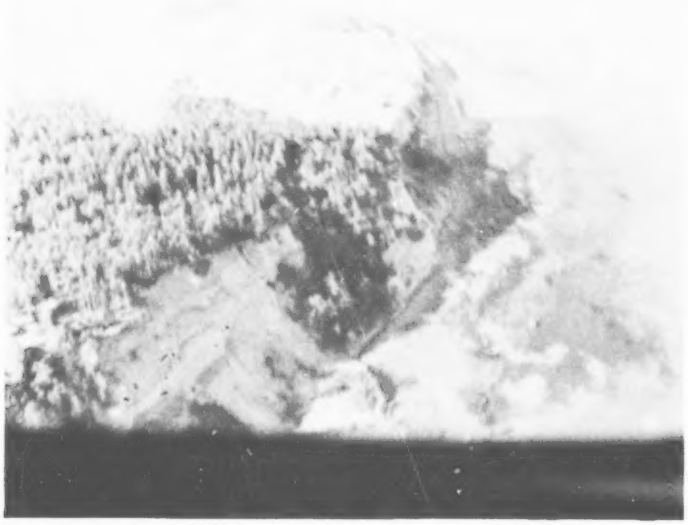
12. Westcott Bay: Haro Strait.

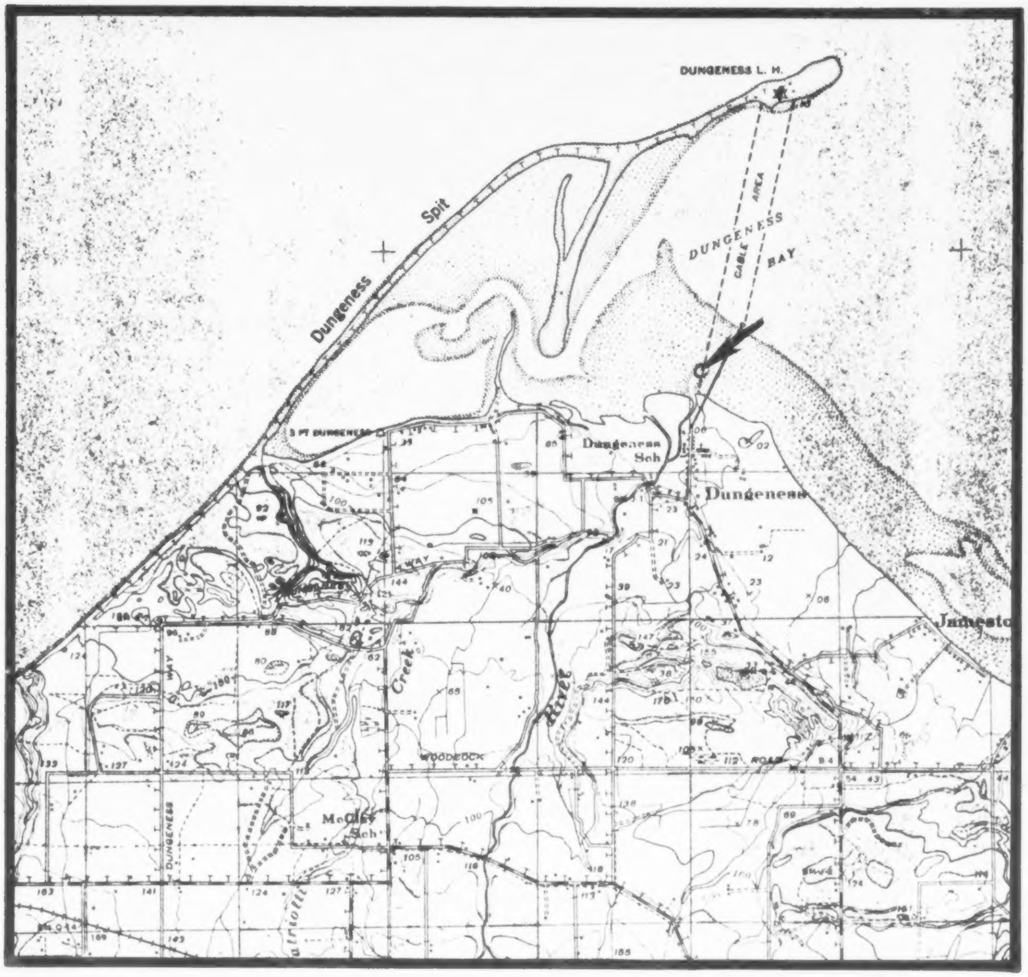

Pt Migley
Lummi Pt.
Gooseberry Pt.
Fishermans Cove
Fern Pt.
Village Pt.
Legoe Bay
Lummi Island
LUMMI
LUMMI
HALE PASSAGE
Cable Area
NORTHBOUND PUGET SOUND TRAFFIC LANE
SEPARATION ZONE
SOUTHBOUND PUGET SOUND TRAFFIC LANE

13. Legoe Bay, Lummi Island: Strait of Georgia.

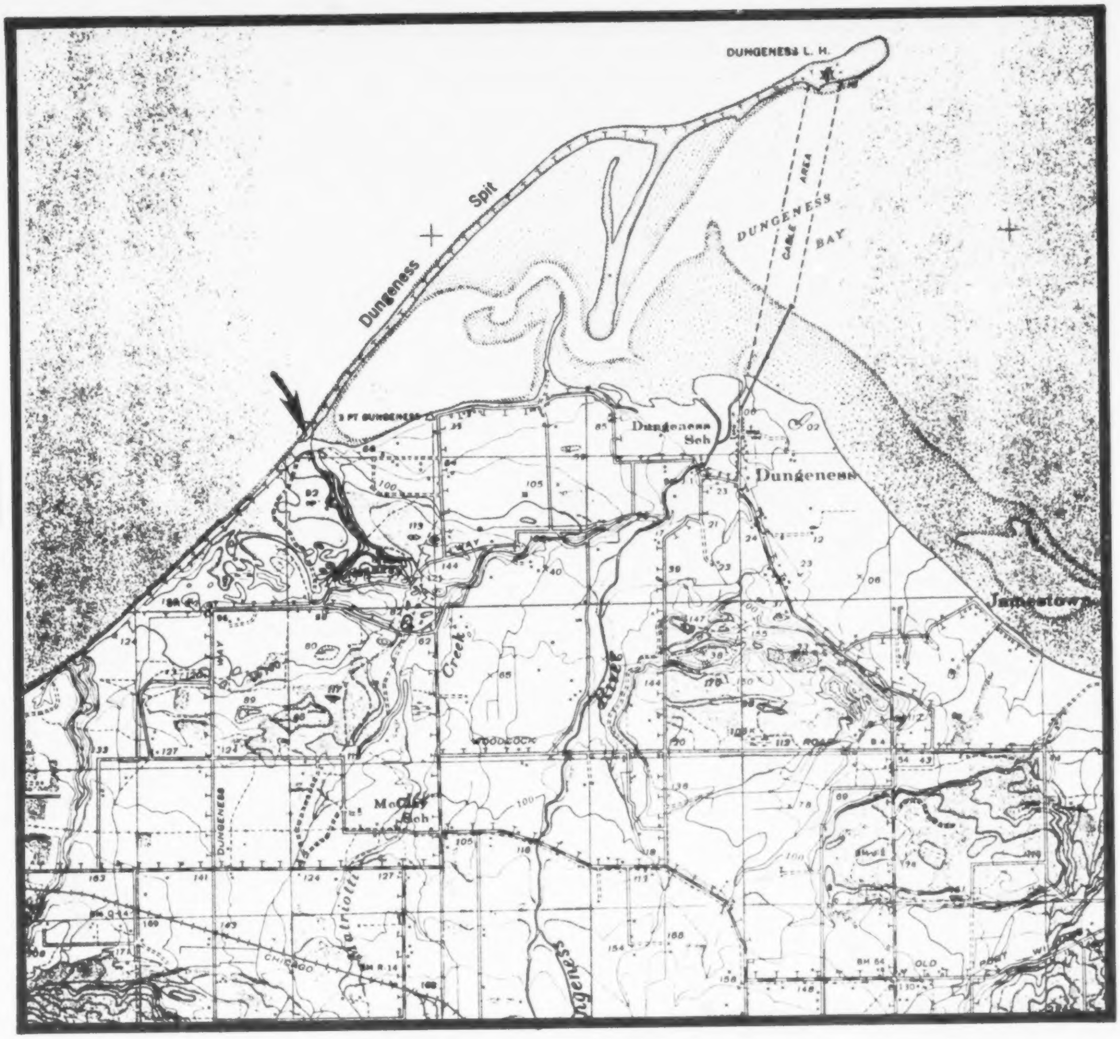

Cape George
Boulders
410 000
FEET
12
CABLE CROSSING
Piles
Diamond Pt
15
13
Gravel
PORT
QUIMPER PENINSULA
Piles
5'
24

14. Cape George: Strait of Juan de Fuca.

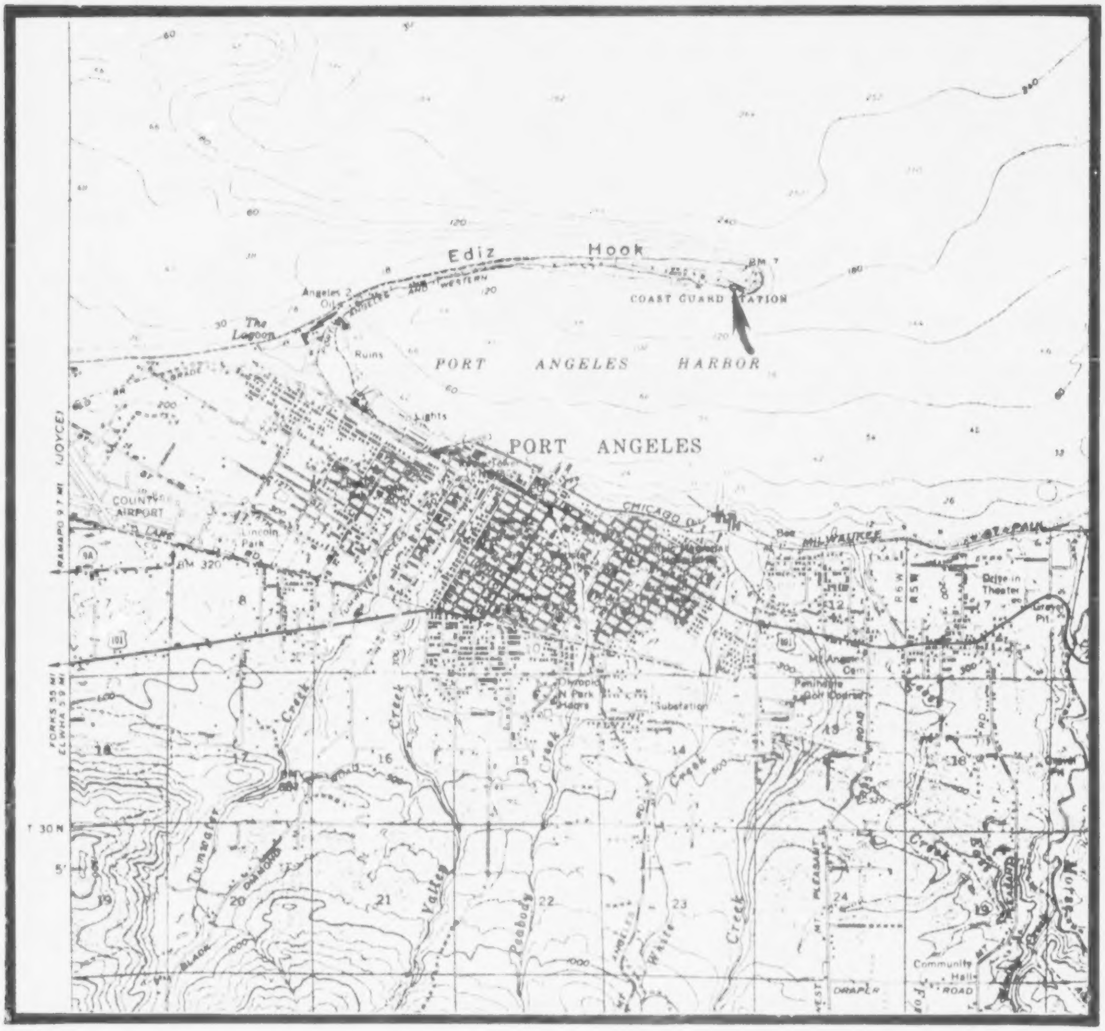



DUNGENESS L. H.
Dungeness Spit
DUNGENESS BAY
CABLE AREA
Dungeness Sch
Dungeness
WOODCOCK
Creek
River
ROAD
McClay Sch
DUNGENESS

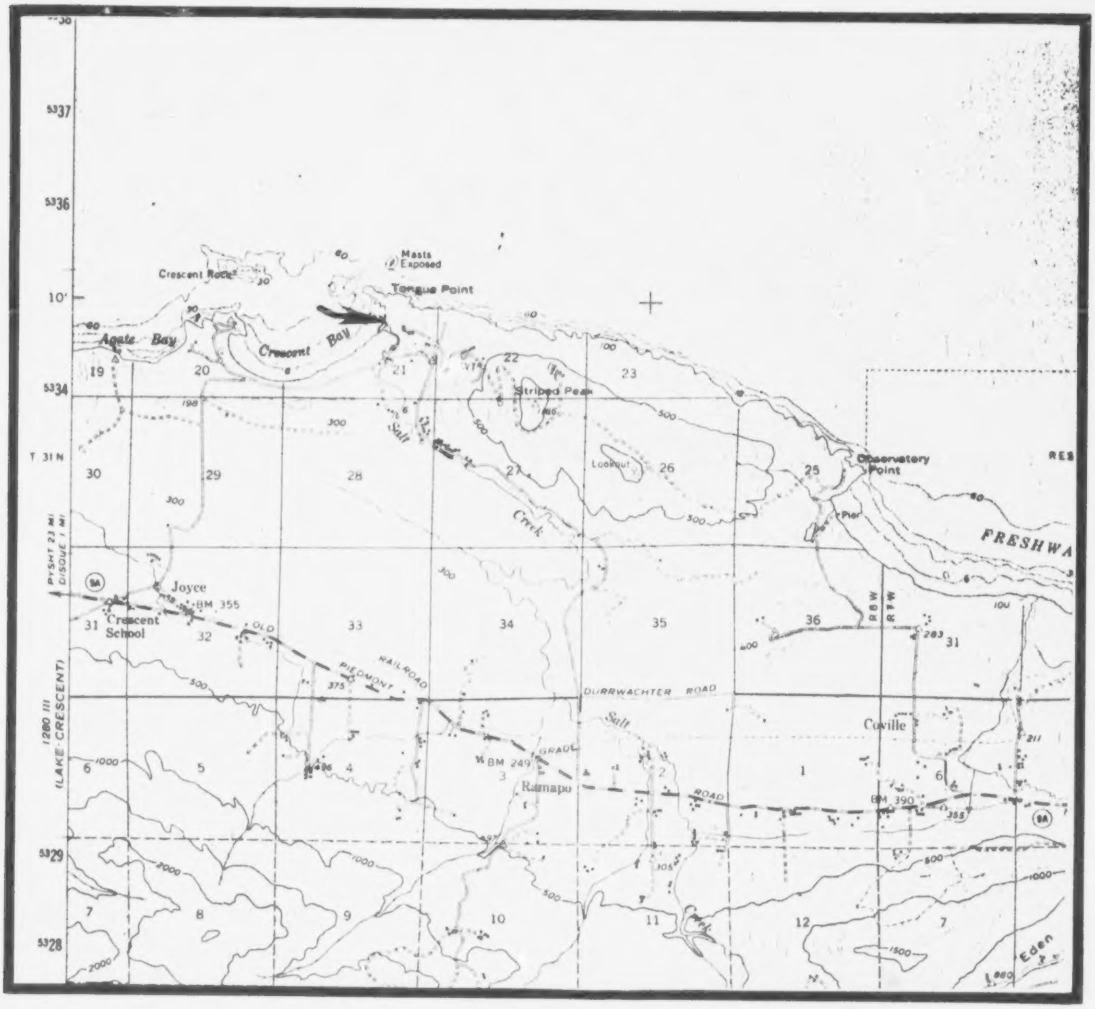
15. Dungeness/Three Crabs:
Strait of Juan de Fuca.


DUNGENESS L. H.
Dungeness Spit
DUNGENESS BAY
CABLE AREA
PT DUNGENESS
Dungeness Sch
Dungeness
Jamestown
Creek
McCoy Sch
Matriotti
Dungeness
WOODCOCK
ROAD
CHICAGO
OLD

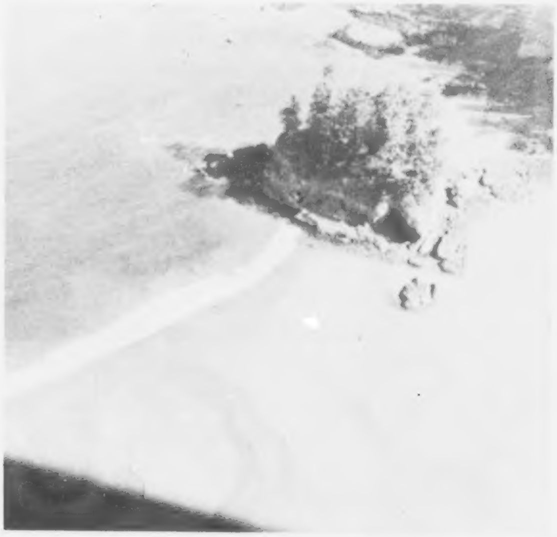
16. Dungeness Spit: Strait of
Juan de Fuca.

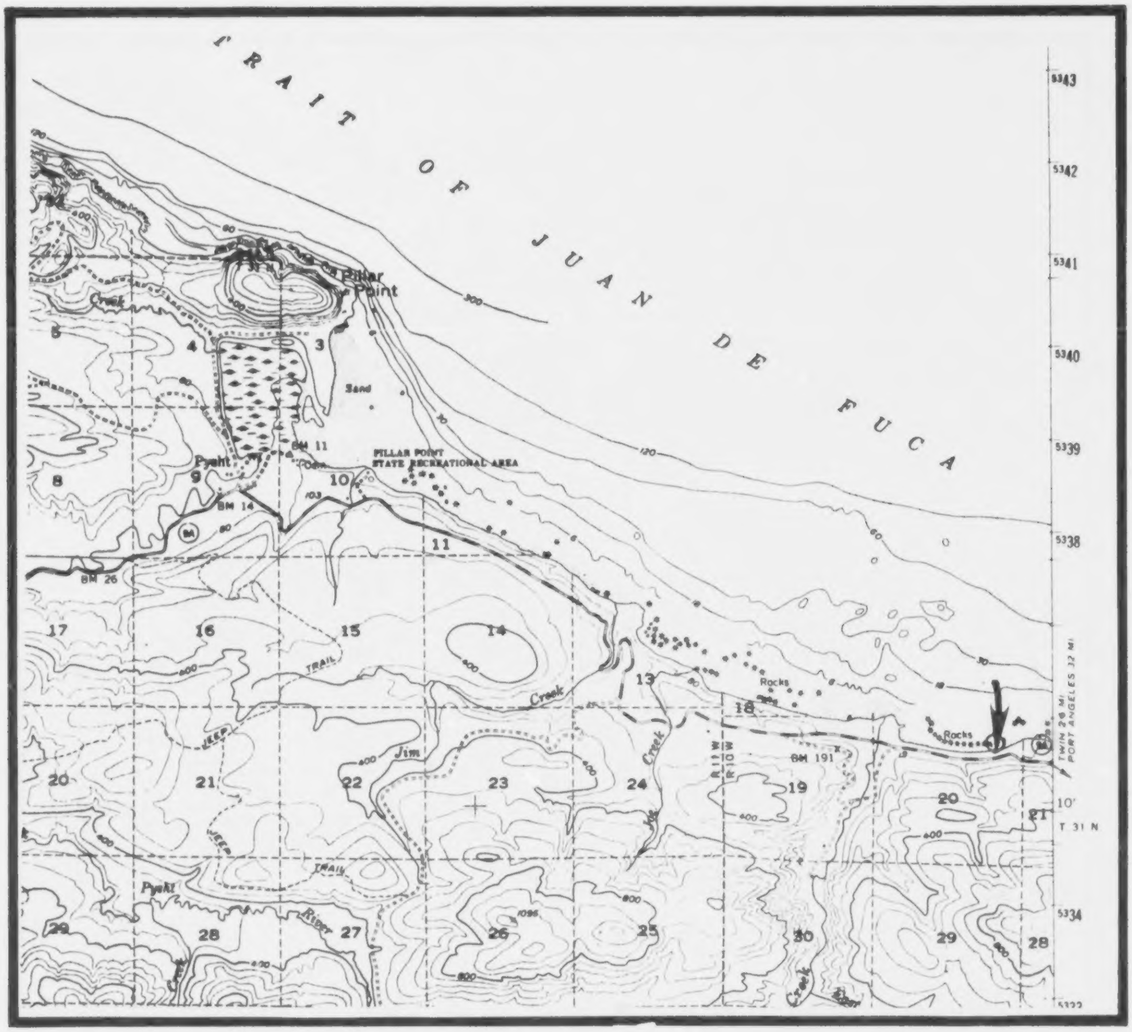

Ediz Hook
COAST GUARD STATION
The Lagoon
Ruins
PORT ANGELES HARBOR
Lights
PORT ANGELES
COUNTY AIRPORT
Lincoln Park
BM 320
CHICAGO
MILWAUKEE
Drive in Theater
Subsetation
Tumwater
Creek
Valley
Peabody
White
Creek
Community Hall
ROAD
DRAPER
T 30 N

17. Ediz Hook: Strait of Juan de Fuca.

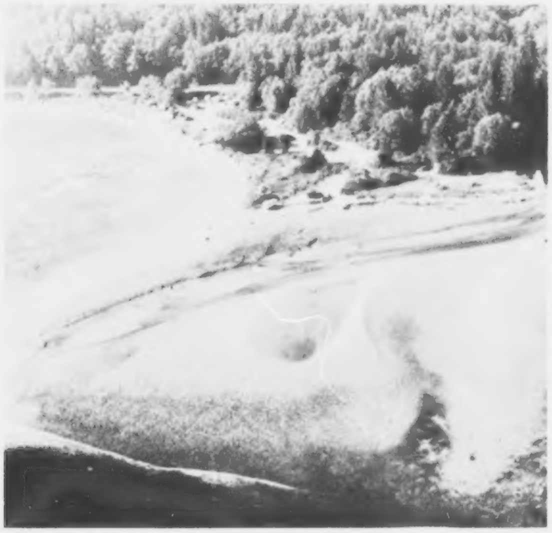

5337
5336
10'
5334
T 31 N
5329
5328
Crescent Rock
Masts Exposed
Tongue Point
Agate Bay
Crescent Bay
Striped Peak
Lookout
Observatory Point
Pier
FRESHWA
RES
Salt Creek
Joyce
BM 355
Crescent School
OLD RAILROAD
PIEDMONT
DURRWACHTER ROAD
Salt
BM 249
Ramapo
GRADE ROAD
Coville
BM 390
Creek
Eden
R 8 W
R 9 W
PYSHT 23 MI.
DISQUE 1 MI.
1260 III
(LAKE CRESCENT)
112
19
20
21
22
23
25
26
27
28
29
30
31
32
33
34
35
36
1
3
4
5
6
7
8
9
10
11
12

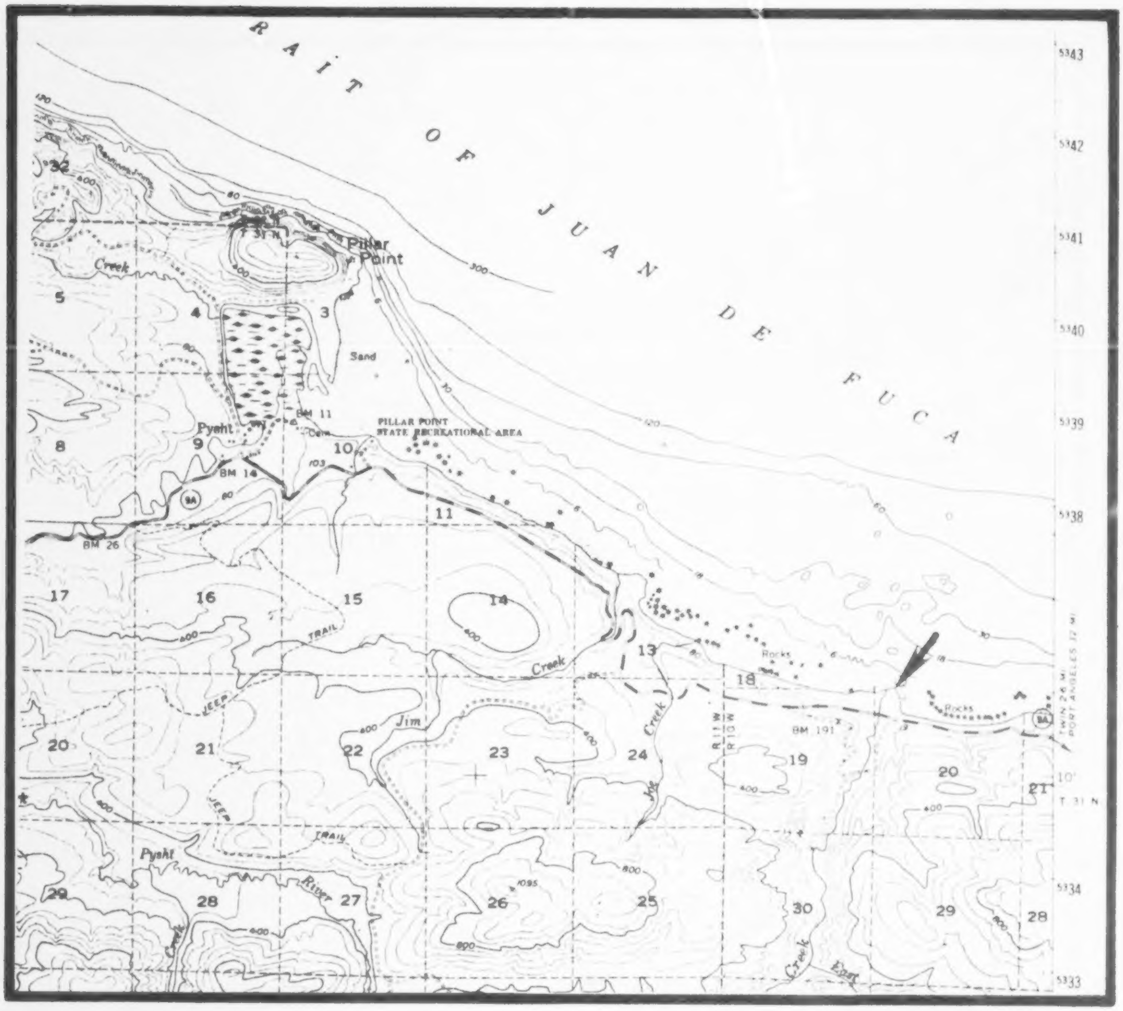
18. Crescent Bay/Tongue Point: Strait of Juan de Fuca.




STRAIT OF JUAN DE FUCA
Pillar Point
PILLAR POINT STATE RECREATIONAL AREA
Pysht
Sand
BM 11
BM 14
BM 26
BM 191
Rocks
Rocks
Creek
Jim
Creek
TRAIL
TRAIL
Pysht River
R 11 W
R 10 W
T 31 N
TWIN 2.6 MI.
PORT ANGELES 32 MI.
5343
5342
5341
5340
5339
5338
5334
10'

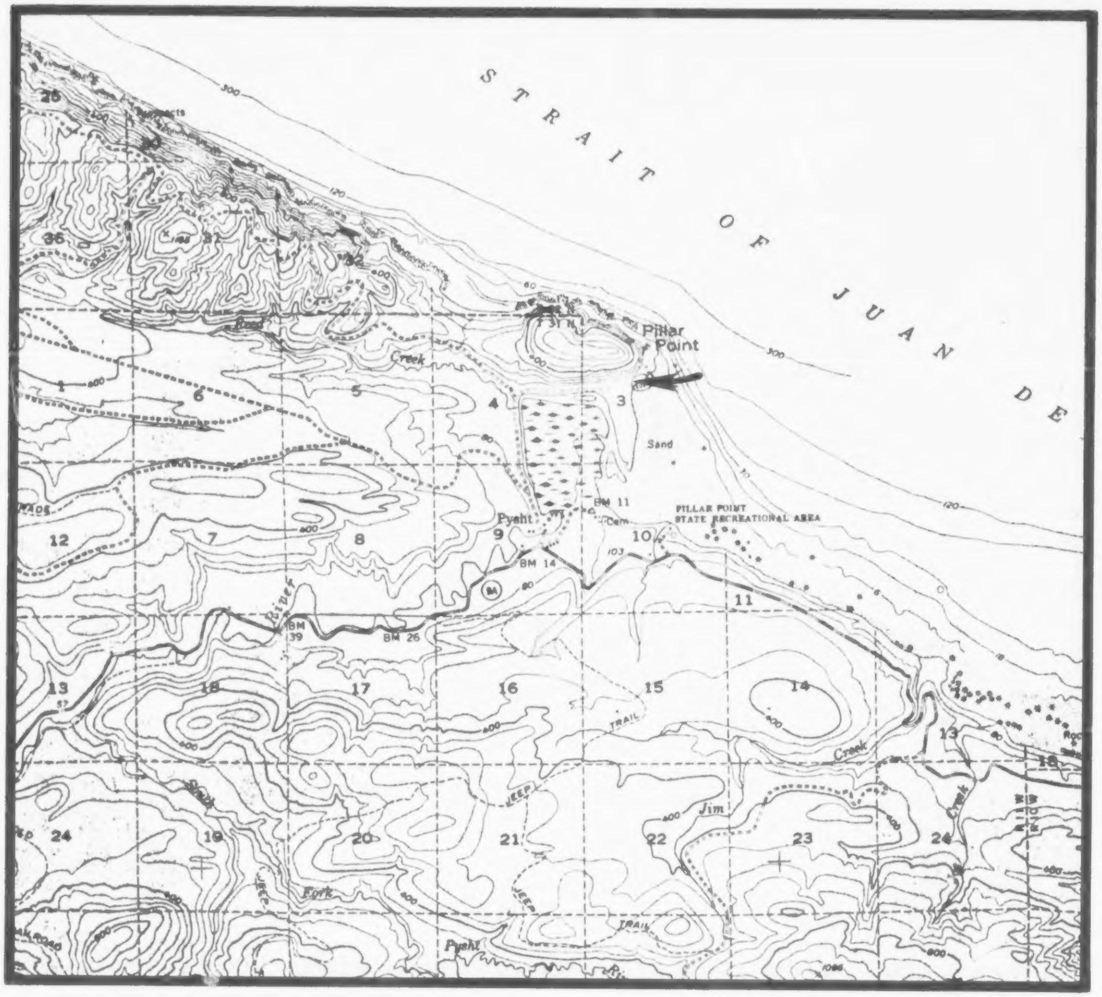
19. Deep Creek Beach (sediment): Strait of Juan de Fuca.





STRAIT OF JUAN DE FUCA
Pillar Point
PILLAR POINT STATE RECREATIONAL AREA
Sand
Pysht
Creek
Jim Creek
Joe Creek
Pysht River
East Creek
JEEP TRAIL
Rocks
BM 11
BM 14
BM 26
BM 191
T 31 N
R 11 W
R 10 W
5343
5342
5341
5340
5339
5338
5334
5333

20. Deep Creek (mussels):
Strait of Juan de Fuca.


STRAIT OF JUAN DE
Pillar Point
Sand
PILLAR POINT STATE RECREATIONAL AREA
Pysht
BM 11
BM 14
BM 26
BM 39
Creek
River
Road
TRAIL
JEEP
Jim
Fork
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
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21
22
23
24
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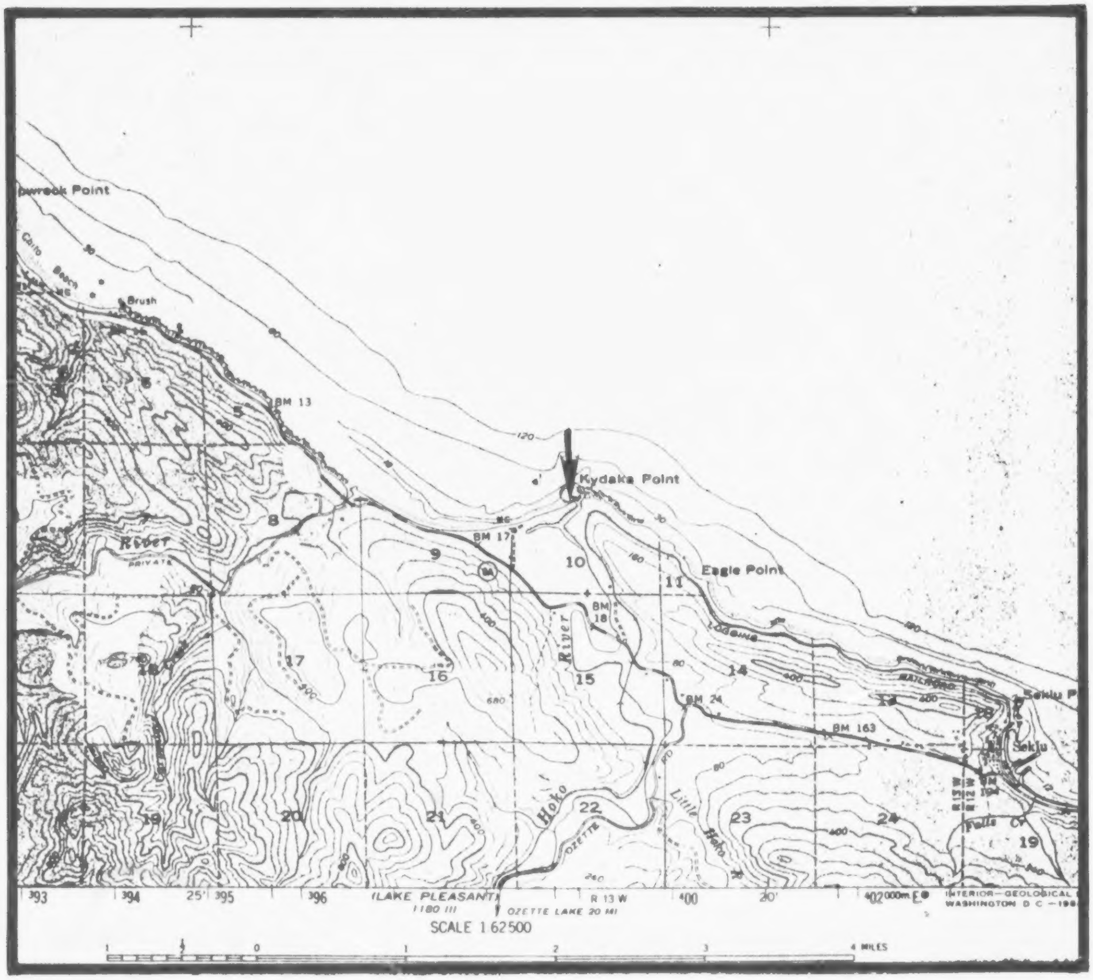
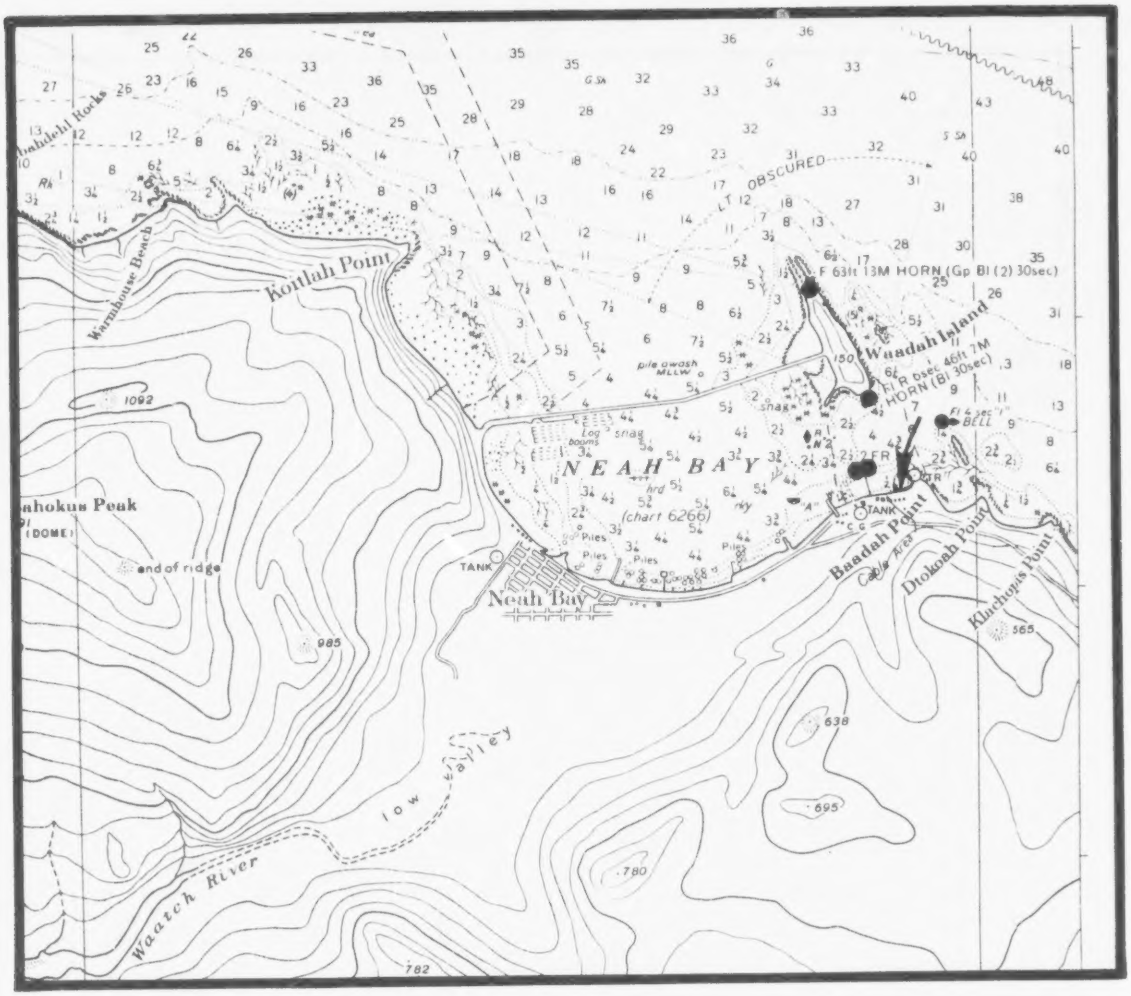
31
32
36

21. Pillar Point: Strait of Juan de Fuca.


Kydaka Point
Eagle Point
Sekiu
BM 13
BM 17
BM 18
BM 24
BM 163
Brush
River
Hoko River
Little Hoko
Falls Cr
Clallam Bay
LAKE PLEASANT
1180 III
OZETTE LAKE 20 MI
R 13 W
SCALE 1:62500
INTERIOR—GEOLOGICAL SURVEY, WASHINGTON D C
4 MILES

22. Kydaka Point: Strait of
Juan de Fuca.


Koitlah Point
Warmhouse Beach
NEAH BAY
Neah Bay
Waadah Island
Baadah Point
Diokoah Point
Klachopis Point
Waatch River
low valley
end of ridge
TANK
F 63ft 13M HORN (Gp Bl (2) 30sec)
OBSCURED
Log booms
snag
Piles
(chart 6266)
BELL
1092
985
638
695
780
782
565

23. Baadah Point: Strait of
Juan de Fuca.

APPENDIX III

ANALYTICAL PROCEDURES

Materials 78

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Sediment Extraction 80

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Materials

Materials contacting the sample were confined to glass, Teflon, metal or residue-free solvents and reagents. This includes caps and lids. All glassware was washed with hot water and laboratory detergent, dried, and rinsed with reagent grade methylene chloride dispensed from a previously cleaned Teflon wash bottle. Teflon and metal foil sheeting and metal implements were also rinsed with methylene chloride before use. Reagents used in this study were of the highest purity obtainable. Solvent ratios are given on a vol./vol. basis.

List of Items:

Laboratory scalpels
Homogenizer: Tekmar tissumizer, #SDT-182EN
Centrifuge tubes: 50 mL: Corning #8422
Test tube racks: A. H. Thomas Co., #9266-N32
Centrifuge: Dupont Instruments/Sorvall, #GLC-2B
Glass (Pyrex) wool: Corning #3950
Dish, aluminum, utility, 57-mm diameter
Teflon caps for centrifuge tubes: Saxillex Corp., Minnetonka, Minn., #0624 teflon closures
Ether peroxides test paper: EM Laboratories, Inc., #10061-9G
Pipets, transfer (Pasteur type): Curtin Matheson Scientific, Inc., #355-123
1-L bottles: Wheaton #219180
Teflon bottle caps: custom-machined from 38 mm o.d. Teflon rod
250 and 600-mL beakers
500-mL Teflon wash bottle: Nalge #2403-0500
150-mL coarse, fritted-glass filter: Corning #36060
1-L separatory funnel with Teflon stopcock: Corning #6402
500-mL Erlenmeyer flask
Chromatography column, 19 mm i.d.: Kontes #K-420280, size 232
Chromatography column, 10.5 mm i.d.: Kontes #K-420280, size 213
500-mL Erlenmeyer flask, 24/40 STJ
Snyder distilling column: Kontes #K-503000, size 121
25-mL concentrator tube: Kontes #K-570050, size 2525
Teflon boiling chips: Bel-Art Products #41001, Pequannock, N.J.
Reflux column: Kontes #K-569251, size 3-19
Vials: Wheaton #223682
Vial caps: Hewlett Packard #5080-8766
Vial capper: Hewlett Packard #871-0979
Capillary GLC columns: Supelco Inc. and Quadrex Corp.
Ball-mill tumbler: model 8-RA, Scott-Murray Manufacturing, 8511 Roosevelt Way, N.E., Seattle, WA (frame, roller bars, motor only)

Constant temperature water bath
Tube heater block: Kontes #K-720003
Tube heater control unit: Kontes #K-720001
Gas chromatograph: Hewlett-Packard #5840A, with flame ionization detector and automatic liquid sampler (#7661A)
Mass spectrometer: Finnigan #3200
Oven with temperature range up to 125°C
Electrobalance, automatic: Cahn Model #4700, Ventron Instruments Corp., Cerritas, Calif.
Balance, top loading: Mettler #P1210
Balance, analytical: Mettler #H33AR
Dessicator: Boekel #1340

Reagents

Methanol: MCB Spectroquality MX0475, Lot 7G13
Petroleum ether: Mallinckrodt Nanograde, #4977
Dichloromethane: Mallinckrodt Nanograde, #3023
Hexane: Burdick and Jackson U-V grade, distilled in glass
Distilled water: carbon-filtered 0.2 mm filtered, and distilled in glass
Ethyl Ether: Burdick and Jackson, Distilled in glass, unpreserved
Silica-gel, 100-200 mesh: MCB #SX144-06
Sodium sulfate, anhydrous: Mallinckrodt, #8064
Sand: MCB #SK78, CB1045
Sodium hydroxide: Mallinckrodt #7708
Copper granules: Mallinckrodt #4649
Hexamethylbenzene (GC internal standard), *n*-declycyclohexane (alkane recovery standard) and 1,3,5,-triisopropylbenzene (aromatic recovery standard): Chemical Samples Co.
Aliphatic and aromatic reference compounds were purchased from: Aldrich, Analabs, Applied Science Labs., and Chemical Samples Co.

Tissue Extraction Procedure For Mussels

Pry open the shells with a clean spatula and separate the two halves by severing the adductor muscle. Scrape the tissue from the shell into a 250-mL beaker for compositing with other individuals.

Blend the tissue with the homogenizer at medium speed for at least 30 sec. Weigh 10 g of sample into a tared 50-mL screwcapped centrifuge tube. Add 6 mL of 4N sodium hydroxide to each sample. Cap each tube tightly with a Teflon screwcap, set tube on vortex stirrer for 1 min and place each sample tube in an oven at 30°C for 18 hr (overnight). Cool the samples to room temperature and shake to check completeness of digestion. If well digested, add 15 mL of peroxide-free diethyl ether, recap tubes tightly, and place on vortex stirrer for 3 min. If not well digested, see Note 1 below. Check the caps for tightness, then centrifuge the tubes at 3,000 RPM for 20 min. If the upper, ether phase is clear, transfer it with a Pasteur pipet to a clean, rinsed concentrator tube and stopper it. Avoid any carryover of the lower aqueous phases. If the supernatant ether phase is not transparent, see Note 2 below before proceeding. Repeat the extraction with 10 mL of ether and combine the extracts. A persistent turbidity indicates the presence of residual water which must be removed by anhydrous sodium sulfate before proceeding.

Attach a reflux column, and add a Teflon boiling chip. Place the apparatus in the tube heater at 80°-85°C.

Shroud the apparatus with aluminum foil to enhance distillation and concentrate the solution to 3-5 mL. Place sample on 10.5-mm diameter chromatography column containing 1 tsp (5 mL) silica gel under ether. Rinse concentrator tube 2x with ether and add to column. Drain extract through silica gel into a clean concentrator tube and rinse down column once with no more than 1 bed volume (ca. 5 mL) of ether. Concentrate to ca. 1 mL, add 2 mL of hexane and a second Teflon boiling chip and concentrate to 1 mL to remove ether completely. The sample is now ready for silica-gel chromatography.

Note 1: Shake sample and return to oven. Check hourly to see if digestion is complete, and, if not, shake again and return to oven, repeating until digestion is complete.

Note 2: If the emulsion layer is small, remove clear ether layer and proceed to the second extraction. If the emulsion layer is extensive, remove the clear ether layer and re-centrifuge the mixture for an additional 20 min. If the emulsion is still extensive, add 1 g of anhydrous sodium sulfate to the mixture, swirl gently, and centrifuge for 20 min. Transfer ether phase to the concentrator tube and proceed with the second extraction.

Sediment Extraction Procedure

To a 100 g sample of sediment in a 1-L bottle, add 50 mL of CH_3OH. Gently agitate the bottles by hand to dewater the sediment. Decant the methanol into a 600-mL beaker and repeat the dewatering step. Add 100 mL of CH_2Cl_2/CH_3OH (2/1), seal bottles with Teflon screw caps and roll on a ball-mill tumbler for 16 hr (overnight) at ca. 75 rpm. Decant the extract into a 600-mL beaker containing the methanolic extracts. Rinse the sample with 5 mL of CH_2Cl_2 and decant again into the 600-mL beaker. Repeat the extraction step for 6 hr, then again for 16 hr (overnight); combine all extracts.

Filter extracts through a fritted-glass filter into a 1-L separatory funnel, and rinse the beaker and filter twice with small amounts of CH_2Cl_2. Gently swirl the filtrate for 2 min with 500 mL of distilled water to partition the CH_3OH between the aqueous and CH_2Cl_2 phases. After the phases separate, drain the lower, CH_2Cl_2, phase into a 500-mL Erlenmeyer flask. Back-extract the aqueous phase with 20 mL of CH_2Cl_2, and add to the previous CH_2Cl_2 phase. After discarding the aqueous phase, repeat the aqueous extraction and CH_2Cl_2 back-extraction steps.

Filter the total CH_2Cl_2 extract through a 19-mm i.d. chromatography column containing 20 mL of silica gel in CH_2Cl_2 covered with a 1-cm layer of sand. Elute the column with 2 bed volumes of CH_2Cl_2 and collect eluate in 500-mL Erlenmeyer flask equipped with a 24/40 joint.

Place the flask, equipped with a Snyder distillation column, in a 60°C water bath and concentrate eluate to ca. 15 mL. Transfer the concentrate to a 25-mL concentrator tube and rinse flask 2x with small amounts of CH_2Cl_2, adding rinses to the tube. Add a boiling chip, attach a reflux column, and concentrate on a tube heater to ca. 1 mL. Add 2 mL of hexane and reconcentrate the extract to ca. 1 mL.

Silica-gel Chromatography

Column Preparation. Prepare columns immediately prior to use. Fill a 10.5-mm i.d. chromatography column with methylene chloride (bulb 1/4 full). Push a 0.5-cm glass-wool plug to the bottom of the column with a glass rod. Measure 15 mL (7 g) of 100-200 mesh silica gel (activated at 125°C for 24 hr, then cooled in a dessicator) into a 250 mL beaker. Add 25 mL of methylene chloride and swirl vigorously to make a slurry. Place a curved-stem funnel into the column such that the tip rests off-center on the bottom of the reservoir just below the surface of the methylene chloride.

Quickly pour the slurry into the funnel and wash the residual slurry into the funnel with methylene chloride from a Teflon wash bottle. The adsorbent particles should quickly settle to the bottom of the column with little turbulence at the settling front. Swirl the column reservoir gently to wash the particles into the column. When the settling front reaches the top of the suspended particles, open the stopcock all the way to complete the settling. After 1 min, carefully add ca. a 1-cm layer of clean sand through a funnel to the top of the gel, followed by 2 cm of anhydrous sodium sulfate for mussel samples (see note 1) or 2 cm of activated copper for sediment samples (see section on copper activation). When the methylene chloride surface is just above the top of the column, add 40 mL of petroleum ether and continue to elute. Close the stopcock when the solvent meniscus almost reaches the top of the column. Discard the rinse eluates.

Sample Chromatography. The sample extract should be in 1 mL of hexane in the concentrator tube. Carefully transfer the extract solution with a Pasteur pipet to the top of the column and elute into a clean 25-mL concentrator tube. Never allow the liquid meniscus to go below the upper surface since air will be entrapped which will disrupt the column. Rinse the concentrator tube 2x with 0.5 mL of petroleum ether each time, add to the column, and elute (see note 2). When the meniscus just reaches the column top, carefully add 15 mL of petroleum ether. Care must be exercised not to disturb the upper surface of the column during each addition. When the meniscus again just reaches the top of the column, add 5 mL of 20% methylene chloride in petroleum ether. When 18 mL has eluted into the concentrator tube receiver, replace it with a second tube. The 18-mL eluate, referred to as fraction 1, contains the saturated hydrocarbons.

Continue eluting into the second tube. As the meniscus just reaches the top of the column, add 25 mL of 40% (v/v) methylene chloride in petroleum ether. Collect 25 mL in second tube. This eluate, fraction 2, contains the unsaturated and aromatic hydrocarbons. Discard any remaining solvent in the column.

Copper Activation. Prior to silica-gel chromatography sediment extracts are passed through activated fine granular copper to remove elemental sulfur. Activated copper should be prepared just prior to use by washing it with concentrated hydrochloric acid (HCl). Rinse the activated copper five times with acetone to remove the HCl and then five times with methylene chloride to remove the acetone.

> Note 1: Both sand and sodium sulfate are dried in an oven at 125°C overnight and cooled in a dessicator for 30 min prior to use.
>
> Note 2: Let the sample and rinses each remain in the copper layer and the sodium sulfate layer for ca. 2 min to remove sulfur and water respectively.

Gas Chromatography (GC)

GC Sample Preparation. Attach a reflux column to the concentrator tube containing the eluate from silica-gel chromatography. Evaporate the solvent in the heater block as previously described. After concentrating to 0.7-1.0 mL, transfer the samples to the GC vials, add 50 μL of internal standard solution (80 ng/μL hexamethylbenzene) and crimp on the Teflon-lined septum caps. Replace the cap each time it is pierced by a syringe to avoid evaporative losses.

GC Apparatus and Modifications. GC analysis is performed on a microprocessor-controlled gas chromatograph (Hewlett-Packard model 5840A) equipped with: an automatic sample injector (model 7671A); a wall-coated, open tubular (WCOT) glass capillary column (20-30 m length, 0.25 mm i.d.); and a hydrogen flame-ionization detector (FID).

The GC sample injection port is modified as described by Ramos, et al. (5).

GC Sample Analysis. Analysis is carried out according to conditions listed in Table III-1. GC Samples in crimp-sealed, septum-capped vials are loaded into the automatic sampler. Then the desired operating conditions are programmed into the microprocessor. A sample volume of 2 μL is injected per analysis. After 5 min, the column temperature is programmed at 4°C/min to 280°C and held for 30 min. Separated compounds are detected by the FID as they emerge from the GC column. The gas chromatogram is constructed by the microprocessor, which prints compound retention times alongside each peak on a strip chart.

Peak areas are automatically computed using "valley to valley" mode baseline correction. Areas are printed in tabular form at the end of the GC run according to retention times. The quantities of compounds represented by the peak areas are also computed automatically by ratio of the individual peak areas to the area of the known amount of internal standard peak. If reference samples are available for compounds of interest, relative response factors for these compounds with respect to the internal standard should be determined experimentally under identical conditions.

Table III-1

Gas Chromatography Conditions

Column type		Column:	30 m x 0.25 mm i.d. wall-coated glass capillary
		Liquid phase:	SE-30 GC (dimethyl siloxane polymer) or SE 54
		Film thickness:	$4\text{-}5\text{x}10^{-4}$mm
Gases	Inlet	Carrier gas:	He
		Split ratio:	10:1 (bypass:column)
		Column flow:	2 mL/min
		Bypass flow:	20 mL/min
	Detector	Makeup (N_2)	30 mL/min
		Air	240 mL/min
		Hydrogen	24 mL/min
Temperatures		Initial Temp:	50°C (for 5 min)
		Program rate:	4°C/min
		Final temp:	280°C
		Injector:	280°C
		Detector:	300°C

Gas Chromatography/Mass Spectrometry (GC/MS).

The identity of compounds detected and measured by GC are confirmed by GC/MS analysis as necessary. A capillary column similar to that used in GC analysis is employed. Effluent from the GC column is fed directly into the ion source. Table III-2 lists analysis conditions. A 1 to 2 -μL sample is injected into the GC/MS while the ion source filament and electron multiplier voltage are turned off. Passage of the solvent peak from GC to MS is noted on the instrument high vacuum gage as a transient rise and fall in pressure. After this, the source filament and multiplier voltage are restored to normal settings and data acquisition by the computer is initiated for mass scans every 2 sec. The GC column is subjected to virtually the same analytical parameters for the GC/MS confirmation run as in the GC detection and measurement run. At the end of the run, the chromatogram is reconstructed (RGC) from the total ion current of each individual scan. Specific ion chromatograms featuring abundancies of ions characteristic of a particular molecular configuration may also be produced. Primarily, compounds shown to be present in the GC/MS chromatogram are identified by comparing their mass spectrum (background subtracted) with standard reference tables of mass spectra or laboratory spectra of reference compounds.

Table III-2

GC/MS Analysis Parameters

GC: Same as Table III-1, except no make-up gas

GC/MS interface temp.: 250°

MS:

Filament emission: 500 A

Electron multiplier voltage: 1800 V

Electron energy: 70 eV

Data acquisition:

Mass range: 80-280 (aromatic samples)
50-300 (alkane samples)

Integration time: 6 msec/scan

Scan time: 2 sec

Dry Weight Determination

Sediment. Thaw sediment and remove pebbles using a spatula or a sieve. Thoroughly mix with a spatula. Add 10-20 g of the sediment to a tared aluminum dish. Weigh and record the weight of the dish and sample. Cover the dish and sample loosely with aluminum foil. Dry the sample in an oven at 120°C for 24 hr, then remove and cool for 30 min in a dessicator. Reweigh and record the dried weight. Calculate percent dry weight as:

$$\frac{\text{weight (dry)} - \text{weight (tare)}}{\text{weight (wet)} - \text{weight (tare)}} \times 100$$

Tissue. Place *ca.* 3 g clean coarse sand and a small glass spatula in an aluminum dish and dry overnight in a 120°C oven. Cool the dish in dessicator for 30 min. Weigh and record as tare weight.

Weigh 0.5 g of sample (to the nearest 0.1 mg) into the dish. Thoroughly mix the sample with the sand, using the spatula taking care to avoid loss of sand granules. Dry the sample in a 120°C oven for 24 hr, then remove and cool in a dessicator for 30 min. Reweigh and record the dried weight. Calculate percent dry weight as:

$$\frac{\text{weight (dry)} - \text{weight (tare)}}{\text{weight (wet)} - \text{weight (tare)}} \times 100$$

Microgravimetric Determinations

Recored the volume of the eluate or extract. Then transfer 25 μL onto the balance pan of a microbalance and allow the solvent to evaporate until weight stabilizes. Record Cahn weight and calculate Total Hydrocarbons (μg/g dry weight) as:

$$\frac{\text{Volume of eluate or extract } (\mu\text{L}) \times \text{Cahn weight}}{25 \times \text{percent dry weight} \times \text{sample weight (g)}} \times 100$$

APPENDIX IV

Individual hydrocarbon data tabulated per site per quarter. All data are reported as ng/g dry weight of sample. ND = not detected.

BIRCH POINT

S E D I M E N T S

n-Alkanes # *carbons*	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
	1A	1B					1A	1B			
10	ND	ND	ND	ND	ND	*o*-Xylene	ND	ND	ND	ND	ND
11	ND	ND	ND	ND	ND	Isopropylbenzene	0.16	ND	ND	ND	ND
12	ND	ND	0.57	1.3	0.82	n-Propylbenzene	0.14	ND	ND	ND	ND
13	0.30	ND	ND	1.6	0.96	Indan	0.13	ND	ND	ND	ND
14	0.21	0.49	0.83	2.4	1.2	1,2,3,4-Tetramethylbenzene	0.27	ND	ND	ND	ND
15	7.5	3.9	8.3	43	12	Naphthalene	1.0	0.45	ND	ND	ND
16	2.2	1.7	2.1	3.5	0.97	Benzothiophene	ND	ND	ND	ND	ND
17	8.5	6.7	7.4	54	16	2-Methylnaphthalene	0.98	0.46	ND	ND	ND
Pristane	5.9	6.3	3.2	27	11	1-Methylnaphthalene	1.0	ND	ND	ND	ND
18	3.1	2.4	3.9	3.8	2.5	Biphenyl	ND	ND	0.47	ND	ND
Phytane	3.1	2.4	1.6	2.4	6.1	2,6-Dimethylnaphthalene	0.5	ND	ND	ND	ND
19	6.3	0.08	2.9	4.2	2.2	2,3,5-Trimethylnaphthalene	1.1	1.9	ND	ND	ND
20	2.0	1.8	4.2	2.1	0.92	Fluorene	0.22	ND	ND	ND	ND
21	4.4	2.8	6.1	2.6	2.3	Dibenzothiophene	0.58	2.0	ND	ND	ND
22	3.3	2.1	12	3.6	2.9	Phenanthrene	2.3	1.9	ND	ND	ND
23	8.1	4.2	21	6.5	7.3	Anthracene	0.22	0.1	ND	ND	ND
24	4.2	2.3	23	2.5	6.9	1-Methylphenanthrene	0.65	1.1	ND	ND	ND
25	16	8.7	33	8.5	9.6	Fluoranthene	ND	ND	1.0	ND	0.77
26	3.6	1.9	19	1.5	7.3	Pyrene	ND	ND	ND	ND	2.7
27	12	8.2	20	10	9.9	Benz(a)anthracene	0.62	ND	ND	ND	18
28	5.7	4.5	13	ND	8.6	Chrysene	11.0	ND	ND	ND	2.4
29	12	8.4	11	ND	8.8	Benzo(e)pyrene	ND	ND	ND	ND	ND
30	ND	ND	3.8	ND	7.1	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	7.3	4.8	ND	ND	8.5	Perylene	ND	ND	ND	ND	ND

M U S S E L S

n-Alkanes # *carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	19	ND	ND	ND	*o*-Xylene	ND	ND	ND	ND
11	17	68	18	ND	Isopropylbenzene	17	ND	ND	ND
12	19	86	ND	ND	n-Propylbenzene	34	ND	ND	ND
13	31	48	ND	ND	Indan	43	ND	ND	ND
14	77	52	ND	ND	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	280	280	350	260	Naphthalene	ND	ND	ND	ND
16	75	58	ND	78	Benzothiophene	ND	ND	ND	ND
17	62	570	ND	27	2-Methylnaphthalene	ND	ND	ND	36
Pristane	890	29	180	170	1-Methylnaphthalene	ND	ND	ND	ND
18	8	ND	ND	ND	Biphenyl	110	ND	10	ND
Phytane	14	ND	ND	ND	2,6-Dimethylnaphthalene	86	ND	ND	ND
19	ND	ND	ND	ND	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	11	ND	ND	ND	Fluorene	ND	ND	ND	ND
21	21	ND	ND	ND	Dibenzothiophene	ND	ND	ND	ND
22	16	ND	ND	ND	Phenanthrene	29	ND	ND	ND
23	37	21	ND	ND	Anthracene	ND	ND	ND	ND
24	25	ND	ND	ND	1-Methylphenanthrene	26	ND	ND	ND
25	59	30	ND	38	Fluoranthene	37	ND	ND	ND
26	27	ND	ND	ND	Pyrene	60	ND	ND	ND
27	94	ND	ND	95	Benz(a)anthracene	ND	ND	ND	7.0
28	ND	ND	ND	ND	Chrysene	ND	ND	ND	ND
29	ND	ND	ND	ND	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

CHERRY POINT

SEDIMENTS

n-Alkanes # *carbons*	Spring			Summer		Fall	Winter	Aromatic hydrocarbons	Spring			Summer		Fall	Winter
	1A	1B	2	1	2				1A	1B	2	1	2		
10	ND	ND	ND	2.2	ND	ND	ND	o-Xylene	ND	ND	ND	ND	ND	ND	ND
11	ND	ND	ND	1.0	1.3	ND	ND	Isopropylbenzene	0.05	0.26	5.5	ND	ND	ND	ND
12	ND	0.16	1.5	0.30	1.1	ND	1.7	n-Propylbenzene	ND	ND	ND	ND	2.5	ND	ND
13	0.52	0.46	1.1	0.70	2.0	ND	1.7	Indan	0.84	0.70	ND	ND	0.92	ND	ND
14	1.4	1.4	2.0	2.8	4.4	ND	2.2	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND	ND	ND	ND
15	4.6	4.1	2.9	16.0	19.0	2.8	3.0	Naphthalene	ND	1.3	2.4	1.9	1.2	ND	ND
16	3.0	2.6	2.7	2.4	4.0	ND	2.4	Benzothiophene	ND	ND	ND	ND	ND	ND	ND
17	6.3	17	6.7	9.9	11.0	4.6	4.8	2-Methylnaphthalene	ND	ND	ND	ND	0.75	0.98	ND
Pristane	3.2	2.6	2.8	5.6	4.9	1.3	5.3	1-Methylnaphthalene	ND	ND	ND	ND	0.86	0.47	ND
18	4.6	4.7	3.5	5.1	5.1	2.6	3.4	Biphenyl	ND	ND	ND	ND	0.43	0.60	ND
Phytane	2.2	2.2	1.7	2.4	2.2	1.4	7.0	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND
19	6.9	7.6	6.5	7.5	6.8	2.8	4.6	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND
20	4.5	4.9	ND	4.8	4.4	2.9	3.5	Fluorene	ND	0.40	ND	1.0	1.3	0.73	ND
21	8.6	9.4	5.3	5.1	4.4	2.7	4.1	Dibenzothiophene	ND	ND	ND	ND	3.1	ND	2.3
22	12	13	1.5	3.4	3.1	3.1	4.0	Phenanthrene	5.7	8.3	4.0	6.8	12	6.7	3.3
23	26	25	6.8	6.1	5.5	5.2	7.9	Anthracene	ND	0.56	ND	0.54	2.0	0.2	ND
24	29	27	ND	3.8	3.8	2.7	5.9	1-Methylphenanthrene	ND	ND	ND	ND	ND	0.18	ND
25	56	51	12	5.4	4.3	6.3	9.5	Fluoranthene	11	12	5.9	15	15	11	6.1
26	39	34	0.40	3.5	2.3	2.4	5.1	Pyrene	7.0	9.4	5.3	5.9	13	5.7	8.0
27	47	41	9.0	8.9	6.7	8.0	10	Benz(a)anthracene	3.5	3.0	ND	2.3	2.6	5.3	ND
28	35	30	2.5	4.4	2.7	1.4	4.4	Chrysene	9.0	8.4	ND	8.1	16	3.9	2.5
29	33	28	5.7	6.9	5.0	5.3	7.5	Benzo(e)pyrene	ND	ND	ND	3.6	ND	2.0	ND
30	20	17	1.9	3.7	ND	0.90	2.8	Benzo(a)pyrene	ND	ND	ND	1.2	ND	ND	ND
31	24	20	4.9	ND	ND	3.5	5.4	Perylene	ND	ND	ND	ND	ND	ND	ND

MUSSELS

n-Alkanes # *carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	78	--	--	--	o-Xylene	ND	--	--	--
11	71	--	--	--	Isopropylbenzene	ND	--	--	--
12	41	--	--	--	n-Propylbenzene	ND	--	--	--
13	38	--	--	--	Indan	26	--	--	--
14	100	--	--	--	1,2,3,4-Tetramethylbenzene	ND	--	--	--
15	350	--	--	--	Naphthalene	ND	--	--	--
16	96	--	--	--	Benzothiophene	ND	--	--	--
17	98	--	--	--	2-Methylnaphthalene	ND	--	--	--
Pristane	57	--	--	--	1-Methylnaphthalene	ND	--	--	--
18	20	--	--	--	Biphenyl	ND	--	--	--
Phytane	31	--	--	--	2,6-Dimethylnaphthalene	120	--	--	--
19	ND	--	--	--	2,3,5-Trimethylnaphthalene	ND	--	--	--
20	21	--	--	--	Fluorene	ND	--	--	--
21	43	--	--	--	Dibenzothiophene	ND	--	--	--
22	69	--	--	--	Phenanthrene	180	--	--	--
23	120	--	--	--	Anthracene	ND	--	--	--
24	67	--	--	--	1-Methylphenanthrene	ND	--	--	--
25	250	--	--	--	Fluoranthene	520	--	--	--
26	59	--	--	--	Pyrene	390	--	--	--
27	200	--	--	--	Benz(a)anthracene	580	--	--	--
28	ND	--	--	--	Chrysene	680	--	--	--
29	ND	--	--	--	Benzo(e)pyrene	ND	--	--	--
30	ND	--	--	--	Benzo(a)pyrene	ND	--	--	--
31	ND	--	--	--	Perylene	ND	--	--	--

SANDY POINT

SEDIMENTS

n-Alkanes *# carbons*	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
	1A	1B					1A	1B			
10	2.4	2.7	ND	ND	ND	*o*-Xylene	ND	ND	ND	ND	ND
11	3.1	3.2	0.60	ND	ND	Isopropylbenzene	0.94	0.06	ND	ND	ND
12	1.9	1.7	3.4	4.6	3.4	*n*-Propylbenzene	ND	0.14	ND	ND	ND
13	3.2	3.2	3.5	4.3	3.9	Indan	ND	0.02	1.1	ND	ND
14	4.1	4.2	4.1	4.5	3.9	1,2,3,4-Tetramethylbenzene	0.07	0.12	ND	ND	ND
15	6.0	6.1	5.7	6.2	5.4	Naphthalene	2.7	2.3	2.3	ND	ND
16	5.5	5.9	3.8	5.0	4.4	Benzothiophene	ND	ND	ND	ND	ND
17	6.7	7.5	4.6	2.4	11	2-Methylnaphthalene	2.5	2.6	0.98	ND	ND
Pristane	1.1	0.95	5.5	30	4.8	1-Methylnaphthalene	1.1	1.0	0.44	ND	ND
18	6.9	7.5	3.6	5.7	5.9	Biphenyl	0.89	0.94	ND	1.2	0.61
Phytane	3.9	4.0	3.9	2.9	3.5	2,6-Dimethylnaphthalene	1.7	1.6	0.99	1.6	1.8
19	11	10	6.4	7.0	7.4	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	1.2
20	3.1	4.1	5.3	6.1	5.4	Fluorene	1.4	1.3	0.64	0.97	2.1
21	11	10	5.8	4.8	7.1	Dibenzothiophene	ND	0.25	ND	0.20	1.6
22	7.5	6.0	4.7	4.5	6.0	Phenanthrene	14	11	5.4	3.8	9.6
23	9.8	7.1	5.7	6.3	8.8	Anthracene	1.3	2.0	ND	ND	5.3
24	9.2	5.0	3.3	4.8	6.4	1-Methylphenanthrene	0.33	0.22	ND	0.51	3.7
25	20	9.6	6.6	5.2	10	Fluoranthene	1.3	1.2	5.2	6.4	33
26	11	4.3	2.7	3.5	6.9	Pyrene	13	10	0.75	5.1	47
27	17	8.7	4.5	6.7	19	Benz(a)anthracene	3.4	3.0	ND	2.7	24
28	12	4.9	2.3	5.0	7.2	Chrysene	11	11	ND	ND	14
29	12	5.9	3.6	8.8	8.7	Benzo(e)pyrene	ND	ND	ND	ND	6.2
30	5.1	ND	1.7	3.3	3.1	Benzo(a)pyrene	ND	ND	ND	ND	8.1
31	8.0	2.8	6.0	4.5	11	Perylene	ND	ND	ND	ND	2.2

MUSSELS

n-Alkanes *# carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	16	ND	29	ND	*o*-Xylene	ND	ND	ND	ND
11	23	ND	38	ND	Isopropylbenzene	ND	ND	ND	ND
12	21	47	32	ND	*n*-Propylbenzene	39	ND	ND	ND
13	13	ND	40	ND	Indan	ND	ND	ND	ND
14	81	64	80	75	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	250	200	360	280	Naphthalene	ND	ND	ND	ND
16	70	45	100	110	Benzothiophene	ND	ND	ND	ND
17	61	220	78	120	2-Methylnaphthalene	ND	ND	ND	ND
Pristane	43	8.5	36	100	1-Methylnaphthalene	ND	ND	470	ND
18	ND	ND	29	47	Biphenyl	ND	ND	ND	ND
Phytane	24	ND	ND	29	2,6-Dimethylnaphthalene	86	ND	ND	ND
19	ND	ND	26	69	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	ND	ND	30	ND	Fluorene	ND	ND	ND	ND
21	18	ND	29	60	Dibenzothiophene	ND	ND	ND	ND
22	24	ND	35	55	Phenanthrene	18	ND	96	23
23	45	ND	53	98	Anthracene	ND	ND	ND	ND
24	42	ND	19	81	1-Methylphenanthrene	ND	ND	1.0	ND
25	77	19	34	110	Fluoranthene	71	ND	39	ND
26	45	14	18	67	Pyrene	81	ND	34	ND
27	110	ND	32	140	Benz(a)anthracene	ND	ND	ND	360
28	ND	ND	ND	64	Chrysene	ND	ND	ND	ND
29	ND	ND	ND	ND	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

MARCH POINT

SEDIMENTS

n-Alkanes # carbons	Spring				Summer		Fall	Winter	Aromatic hydrocarbons	Spring				Summer		Fall	Winter
	1A	1B	2A	2B	1	2				1A	1B	2A	2B	1	2		
10	ND	ND	ND	ND	2.1	1.2	ND	ND	o-Xylene	ND	3.6	ND	ND	ND	ND	ND	ND
11	0.27	ND	ND	ND	3.2	2.3	ND	ND	Isopropylbenzene	0.15	0.47	0.29	0.21	ND	ND	ND	ND
12	0.52	1.4	0.64	6.0	1.4	1.3	3.8	2.7	n-Propylbenzene	0.37	0.81	ND	ND	1.2	3.4	ND	ND
13	2.1	2.5	2.4	7.0	4.2	3.5	7.7	4.1	Indan	0.17	0.68	1.6	0.40	ND	ND	ND	ND
14	4.0	4.4	5.2	10	7.7	5.8	4.3	6.0	1,2,3,4-Tetramethylbenzene	0.18	0.26	ND	ND	ND	ND	ND	ND
15	8.9	11	14	20	16	12	15	9.7	Naphthalene	3.9	5.2	2.5	5.7	4.3	6.0	ND	ND
16	8.9	12	16	18	12	8.7	5.9	10	Benzothiophene	ND	ND	ND	ND	ND	ND	ND	ND
17	14	19	27	23	21	15	18	18	2-Methylnaphthalene	4.0	4.4	ND	4.8	2.8	4.3	2.9	ND
Pristane	6.9	30	23	66	24	19	23	12	1-Methylnaphthalene	1.6	1.7	0.52	1.9	ND	1.6	1.6	ND
18	12	22	30	21	21	13	8.6	13	Biphenyl	1.4	1.3	ND	0.25	0.36	0.92	0.03	0.93
Phytane	7.4	18	12	45	13	8.7	4.2	7.1	2,6-Dimethylnaphthalene	1.6	1.6	ND	3.8	1.5	2.6	0.64	2.2
19	21	32	38	6.8	28	18	16	14	2,3,5-Trimethylnaphthalene	2.1	1.7	ND	5.8	0.38	0.53	0.63	ND
20	11	20	25	20	19	12	8.3	9.9	Fluorene	1.9	1.6	1.0	4.4	2.8	4.6	0.29	3.0
21	16	21	26	22	24	12	10	11	Dibenzothiophene	0.28	0.30	ND	1.50	0.79	1.2	ND	0.89
22	17	21	24	3.3	14	7.8	7.7	7.6	Phenanthrene	18	14	19	62	24	50	9.6	12
23	27	28	30	45	17	11	16	9.3	Anthracene	6.1	3.1	3.5	10	4.2	7.9	1.5	1.6
24	29	25	27	54	9.4	5.9	8.7	5.5	1-Methylphenanthrene	1.3	0.90	0.2	2.5	1.3	1.7	0.48	1.0
25	54	43	41	72	16	7.8	21	9.0	Fluoranthene	13	7.1	46	73	33	62	11	16
26	27	21	23	43	7.1	4.5	8.3	4.5	Pyrene	22	16	52	77	30	94	8.3	24
27	39	28	29	45	17	13	41	7.3	Benz(a)anthracene	7.9	7.6	13	21	5.3	16	8.5	14
28	26	17	18	30	19	17	9.7	10	Chrysene	19	20	34	48	12	48	6.5	5.4
29	29	20	23	30	18	9.2	3.2	13	Benzo(e)pyrene	ND	ND	ND	ND	5.0	ND	4.2	2.3
30	9.6	5.4	9.0	13	4.0	7.9	19	16	Benzo(a)pyrene	ND	ND	ND	ND	3.8	ND	4.2	0.35
31	16	12	16	17	12	9.8	24	10	Perylene	ND	ND	ND	ND	2.0	ND	0.73	ND

MUSSELS

n-Alkanes # carbons	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	69	150	410	ND	o-Xylene	ND	ND	ND	ND
11	76	180	360	180	Isopropylbenzene	ND	ND	ND	ND
12	53	110	250	65	n-Propylbenzene	63	ND	ND	ND
13	39	45	110	69	Indan	17	ND	ND	ND
14	80	55	81	61	1,2,3,4-Tetramethylbenzene	76	ND	ND	ND
15	170	200	190	290	Naphthalene	ND	ND	33	ND
16	34	40	52	140	Benzothiophene	ND	ND	ND	ND
17	58	68	87	190	2-Methylnaphthalene	ND	ND	20	ND
Pristane	100	82	620	360	1-Methylnaphthalene	ND	ND	190	ND
18	9.0	ND	19	ND	Biphenyl	ND	ND	ND	ND
Phytane	27	ND	100	110	2,6-Dimethylnaphthalene	60	ND	ND	ND
19	ND	ND	63	ND	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	9.4	ND	29	ND	Fluorene	ND	ND	ND	ND
21	11	22	31	ND	Dibenzothiophene	ND	ND	ND	ND
22	12	ND	32	ND	Phenanthrene	68	49	160	200
23	28	33	85	78	Anthracene	ND	61	ND	ND
24	22	ND	18	44	1-Methylphenanthrene	ND	ND	39	ND
25	60	21	38	70	Fluoranthene	140	93	100	1200
26	25	ND	10	52	Pyrene	50	ND	45	910
27	63	ND	19	120	Benz(a)anthracene	ND	ND	ND	280
28	ND	ND	ND	49	Chrysene	ND	ND	ND	160
29	ND	ND	26	110	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

SHANNON POINT

SEDIMENTS

n-Alkanes # *carbons*	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
	1A	1B					1A	1B			
10	1.1	0.97	1.1	ND	ND	o-Xylene	2.9	1.3	ND	ND	ND
11	0.39	0.31	1.4	ND	ND	Isopropylbenzene	ND	ND	ND	ND	ND
12	ND	ND	4.8	ND	1.5	n-Propylbenzene	ND	ND	ND	ND	ND
13	ND	ND	5.8	ND	1.3	Indan	ND	ND	ND	ND	ND
14	0.90	ND	2.1	ND	1.5	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND	ND
15	3.4	0.71	6.5	3.0	2.7	Naphthalene	1.9	ND	2.0	ND	ND
16	3.7	0.49	8.2	2.8	2.6	Benzothiophene	ND	ND	ND	ND	ND
17	13	2.0	14	3.7	4.4	2-Methylnaphthalene	1.7	ND	ND	ND	ND
Pristane	5.7	0.98	8.4	3.4	2.8	1-Methylnaphthalene	0.9	ND	ND	ND	ND
18	10	2.4	6.9	4.2	3.3	Biphenyl	1.4	ND	0.16	ND	ND
Phytane	5.2	ND	2.7	2.9	0.14	2,6-Dimethylnaphthalene	1.0	ND	ND	ND	ND
19	9.1	3.1	6.9	9.6	5.7	2,3,5-Trimethylnaphthalene	3.0	ND	ND	ND	ND
20	17	2.3	4.8	8.4	3.4	Fluorene	5.4	ND	ND	ND	0.58
21	46	3.0	11	9.4	3.8	Dibenzothiophene	0.17	ND	ND	ND	ND
22	140	2.2	6.8	6.0	3.2	Phenanthrene	4.4	0.70	1.7	0.36	2.4
23	280	3.9	5.6	8.4	4.1	Anthracene	ND	ND	ND	0.51	0.14
24	380	1.5	10	4.7	2.6	1-Methylphenanthrene	9.5	0.20	2.6	ND	0.34
25	510	11	15	84	4.4	Fluoranthene	160	150	1.2	ND	3.5
26	340	1.3	8.1	4.5	2.4	Pyrene	1.9	ND	ND	ND	3.9
27	280	6.2	12	11	5.9	Benz(a)anthracene	3.6	3.5	ND	ND	0.55
28	200	2.2	5.9	1.1	2.7	Chrysene	19	ND	ND	ND	0.36
29	130	4.8	7.1	ND	6.0	Benzo(e)pyrene	ND	ND	ND	ND	0.36
30	5.3	0.23	5.8	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	73	6.2	10	ND	ND	Perylene	11	ND	ND	ND	ND

MUSSELS

n-Alkanes # *carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	21	ND	--	--	o-Xylene	ND	6.3	--	--
11	24	30	--	--	Isopropylbenzene	ND	ND	--	--
12	ND	52	--	--	n-Propylbenzene	ND	ND	--	--
13	ND	18	--	--	Indan	ND	ND	--	--
14	ND	120	--	--	1,2,3,4-Tetramethylbenzene	ND	ND	--	--
15	110	160	--	--	Naphthalene	ND	ND	--	--
16	20	65	--	--	Benzothiophene	ND	ND	--	--
17	45	160	--	--	2-Methylnaphthalene	ND	ND	--	--
Pristane	360	200	--	--	1-Methylnaphthalene	ND	ND	--	--
18	12	ND	--	--	Biphenyl	ND	ND	--	--
Phytane	100	ND	--	--	2,6-Dimethylnaphthalene	ND	ND	--	--
19	ND	ND	--	--	2,3,5-Trimethylnaphthalene	ND	ND	--	--
20	26	ND	--	--	Fluorene	ND	ND	--	--
21	26	59	--	--	Dibenzothiophene	ND	ND	--	--
22	38	ND	--	--	Phenanthrene	15	ND	--	--
23	47	17	--	--	Anthracene	ND	ND	--	--
24	40	ND	--	--	1-Methylphenanthrene	100	2.7	--	--
25	61	6.3	--	--	Fluoranthene	ND	ND	--	--
26	31	ND	--	--	Pyrene	24	ND	--	--
27	44	ND	--	--	Benz(a)anthracene	ND	ND	--	--
28	ND	ND	--	--	Chrysene	ND	ND	--	--
29	ND	ND	--	--	Benzo(e)pyrene	ND	ND	--	--
30	ND	ND	--	--	Benzo(a)pyrene	ND	ND	--	--
31	ND	ND	--	--	Perylene	ND	ND	--	--

ALEXANDER BEACH

SEDIMENTS

n-Alkanes # carbons	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
	1A	1B					1A	1B			
10	1.4	0.35	ND	ND	ND	o-Xylene	2.5	0.80	ND	ND	ND
11	1.3	0.27	0.20	ND	ND	Isopropylbenzene	1.9	0.70	2.0	ND	ND
12	ND	ND	0.49	1.5	0.70	n-Propylbenzene	1.4	0.50	1.1	ND	ND
13	ND	ND	0.65	1.4	0.79	Indan	ND	ND	ND	ND	ND
14	0.39	0.25	0.73	1.7	1.2	1,2,3,4-Tetramethylbenzene	ND	0.10	ND	ND	ND
15	2.1	0.18	1.7	7.4	1.9	Naphthalene	1.7	1.0	0.86	ND	ND
16	2.2	0.18	1.5	2.1	2.0	Benzothiophene	ND	ND	ND	ND	ND
17	4.1	3.2	2.8	6.1	ND	2-Methylnaphthalene	0.40	0.40	0.40	ND	ND
Pristane	110	98	150	ND	ND	1-Methylnaphthalene	ND	ND	0.10	ND	ND
18	3.7	2.8	1.3	3.0	2.8	Biphenyl	ND	ND	ND	ND	ND
Phytane	2.3	ND	0.97	1.4	1.6	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND
19	7.1	4.9	3.1	5.8	3.8	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND
20	5.1	3.5	2.3	4.9	3.3	Fluorene	ND	0.20	0.084	ND	0.88
21	7.8	5.4	2.8	4.9	3.9	Dibenzothiophene	ND	ND	ND	ND	ND
22	7.9	5.6	0.13	4.7	2.9	Phenanthrene	0.80	2.7	1.3	ND	1.9
23	12	9.5	ND	9.4	4.9	Anthracene	ND	ND	ND	ND	ND
24	9.4	7.7	ND	5.3	2.3	1-Methylphenanthrene	ND	0.60	0.19	ND	0.20
25	15	16	4.1	12	6.8	Fluoranthene	6.9	9.2	2.5	ND	3.8
26	11	6.5	ND	4.5	2.5	Pyrene	0.70	2.7	ND	ND	3.1
27	12	9.5	0.15	12	6.0	Benz(a)anthracene	0.60	1.7	ND	5.9	ND
28	7.8	6.2	ND	4.6	2.7	Chrysene	ND	ND	ND	ND	0.45
29	8.7	7.0	4.3	13	5.4	Benzo(e)pyrene	ND	ND	ND	ND	ND
30	4.1	3.2	ND	5.6	ND	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	10	7.7	ND	11	ND	Perylene	ND	ND	ND	ND	ND

MUSSELS

n-Alkanes # carbons	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	18	ND	11	ND	o-Xylene	ND	ND	ND	ND
11	59	ND	28	ND	Isopropylbenzene	ND	ND	ND	ND
12	150	25	50	ND	n-Propylbenzene	48	ND	ND	ND
13	5.9	ND	36	75	Indan	27	ND	ND	ND
14	81	57	200	270	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	220	300	830	450	Naphthalene	ND	ND	15	ND
16	590	92	98	100	Benzothiophene	ND	ND	ND	ND
17	77	190	11	170	2-Methylnaphthalene	23	ND	ND	ND
Pristane	5000	1200	3400	3700	1-Methylnaphthalene	13	ND	ND	ND
18	54	55	12	85	Biphenyl	ND	ND	ND	ND
Phytane	1600	110	47	540	2,6-Dimethylnaphthalene	ND	ND	ND	ND
19	500	23	37	ND	2,3,5-Trimethylnaphthalene	31	ND	ND	ND
20	130	38	22	71	Fluorene	150	ND	ND	ND
21	29	64	ND	66	Dibenzothiophene	ND	ND	ND	ND
22	77	ND	22	50	Phenanthrene	31	ND	18	63
23	49	44	55	84	Anthracene	ND	ND	ND	ND
24	25	35	23	56	1-Methylphenanthrene	83	ND	ND	ND
25	89	51	750	190	Fluoranthene	14	ND	ND	350
26	64	83	27	48	Pyrene	49	ND	7.4	ND
27	260	49	120	140	Benz(a)anthracene	ND	ND	ND	11
28	370	84	19	ND	Chrysene	ND	ND	ND	5.3
29	610	ND	40	90	Benzo(e)pyrene	ND	ND	ND	ND
30	830	52	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	1300	ND	ND	ND	Perylene	ND	ND	ND	ND

FORT CASEY

SEDIMENTS

n-Alkanes	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
# carbons	1A	1B					1A	1B			
10	ND	ND	ND	ND	ND	o-Xylene	ND	ND	ND	ND	ND
11	ND	ND	ND	ND	ND	Isopropylbenzene	ND	ND	ND	ND	ND
12	0.50	ND	3.5	1.6	3.6	n-Propylbenzene	0.43	ND	ND	ND	ND
13	0.50	ND	3.2	1.8	3.5	Indan	0.32	ND	1.1	ND	ND
14	1.3	ND	5.8	2.5	3.8	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND	ND
15	2.1	ND	3.6	3.0	3.1	Naphthalene	ND	ND	ND	ND	ND
16	2.1	ND	4.2	3.2	2.7	Benzothiophene	ND	ND	ND	ND	ND
17	1.3	ND	7.1	3.9	2.6	2-Methylnaphthalene	ND	ND	ND	ND	ND
Pristane	ND	ND	1.5	3.1	2.2	1-Methylnaphthalene	ND	ND	ND	ND	ND
18	2.3	ND	4.0	3.6	2.5	Biphenyl	ND	ND	ND	ND	ND
Phytane	ND	ND	1.2	0.90	1.1	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND
19	2.2	ND	4.6	3.2	3.1	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND
20	1.4	ND	5.2	3.2	2.2	Fluorene	ND	ND	ND	ND	ND
21	2.6	ND	5.5	2.5	2.2	Dibenzothiophene	ND	ND	ND	ND	ND
22	2.6	ND	3.7	2.2	2.2	Phenanthrene	0.66	ND	ND	ND	1.7
23	3.7	0.15	3.3	3.0	3.5	Anthracene	ND	ND	ND	ND	0.63
24	3.4	0.43	2.5	1.8	2.7	1-Methylphenanthrene	ND	ND	ND	ND	0.04
25	5.6	0.31	4.8	2.4	2.9	Fluoranthene	1.9	0.42	ND	ND	ND
26	2.6	ND	2.3	1.6	2.2	Pyrene	ND	ND	ND	ND	1.4
27	3.8	ND	3.6	2.9	2.7	Benz(a)anthracene	ND	ND	ND	ND	ND
28	3.3	ND	3.6	0.92	2.3	Chrysene	ND	ND	ND	ND	ND
29	3.7	ND	3.8	2.2	3.4	Benzo(e)pyrene	ND	ND	ND	ND	ND
30	ND	ND	ND	ND	1.4	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	ND	ND	ND	ND	1.9	Perylene	ND	ND	ND	ND	ND

KEYSTONE

MUSSELS

n-Alkanes *# carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	34	ND	ND	ND	o-Xylene	ND	ND	ND	ND
11	45	ND	ND	ND	Isopropylbenzene	19	ND	ND	ND
12	47	39	ND	28	n-Propylbenzene	23	95	ND	ND
13	37	27	79	56	Indan	30	ND	ND	ND
14	150	120	180	140	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	300	270	520	270	Naphthalene	ND	ND	ND	ND
16	52	87	110	110	Benzothiophene	ND	ND	ND	ND
17	290	90	78	140	2-Methylnaphthalene	ND	ND	ND	ND
Pristane	37	830	460	270	1-Methylnaphthalene	ND	ND	ND	ND
18	14	ND	11	57	Biphenyl	ND	ND	ND	ND
Phytane	30	ND	74	93	2,6-Dimethylnaphthalene	220	ND	ND	ND
19	54	ND	ND	29	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	20	ND	ND	56	Fluorene	ND	ND	ND	ND
21	75	ND	ND	61	Dibenzothiophene	ND	ND	ND	ND
22	34	ND	ND	62	Phenanthrene	170	ND	ND	ND
23	44	ND	51	52	Anthracene	ND	ND	ND	ND
24	37	ND	54	75	1-Methylphenanthrene	160	16	ND	ND
25	170	ND	72	47	Fluoranthene	410	26	ND	ND
26	41	ND	39	71	Pyrene	280	ND	ND	270
27	ND	ND	68	37	Benz(a)anthracene	280	ND	ND	150
28	ND	ND	42	61	Chrysene	300	ND	ND	38
29	ND	ND	88	130	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

NAVAL AIR STATION/WHIDBEY ISLAND

SEDIMENTS

n-Alkanes	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
# *carbons*	1A	1B					1A	1B			
10	0.28	0.28	ND	ND	ND	o-Xylene	0.54	1.4	ND	ND	ND
11	ND	ND	ND	ND	ND	Isopropylbenzene	ND	ND	ND	ND	ND
12	ND	ND	1.0	ND	0.20	n-Propylbenzene	ND	ND	ND	ND	ND
13	ND	ND	1.2	ND	1.0	Indan	ND	ND	ND	ND	ND
14	ND	ND	1.5	ND	1.4	1,2,3,4-Tetramethylbenzene	ND	ND	0.69	ND	ND
15	ND	ND	1.5	ND	1.3	Naphthalene	ND	ND	2.4	ND	ND
16	ND	ND	1.9	ND	1.3	Benzothiophene	ND	ND	ND	ND	ND
17	0.37	0.23	4.1	ND	0.070	2-Methylnaphthalene	ND	ND	ND	ND	ND
Pristane	0.68	0.34	2.7	ND	2.5	1-Methylnaphthalene	ND	ND	ND	ND	ND
18	0.38	0.39	2.6	ND	1.1	Biphenyl	ND	ND	0.079	ND	ND
Phytane	ND	ND	1.1	ND	1.8	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND
19	0.17	0.51	3.6	0.33	1.1	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND
20	0.40	0.39	4.0	0.57	1.2	Fluorene	ND	ND	ND	ND	ND
21	ND	0.44	6.6	1.1	1.4	Dibenzothiophene	ND	ND	ND	ND	4.3
22	0.44	ND	9.5	1.1	1.2	Phenanthrene	ND	ND	1.0	ND	1.1
23	0.22	ND	14.0	2.5	2.4	Anthracene	ND	ND	ND	ND	ND
24	ND	ND	15.0	1.4	1.2	1-Methylphenanthrene	ND	ND	ND	ND	ND
25	4.7	4.0	19.0	3.1	2.1	Fluoranthene	3.5	3.1	2.0	1.5	2.5
26	ND	ND	11.0	1.5	1.2	Pyrene	ND	ND	ND	0.46	1.1
27	1.3	ND	12.0	4.3	2.4	Benz(a)anthracene	ND	ND	ND	ND	ND
28	ND	ND	7.8	1.1	ND	Chrysene	ND	ND	ND	ND	ND
29	ND	ND	7.7	3.6	1.8	Benzo(e)pyrene	ND	ND	ND	ND	ND
30	ND	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	ND	ND	ND	2.3	ND	Perylene	ND	ND	ND	ND	ND

MUSSELS

n-Alkanes # *carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	150	ND	23	ND	o-Xylene	ND	ND	ND	ND
11	470	64	72	74	Isopropylbenzene	ND	ND	ND	ND
12	410	100	130	68	n-Propylbenzene	110	ND	ND	ND
13	180	54	75	58	Indan	21	ND	ND	ND
14	170	62	200	74	1,2,3,4-Tetramethylbenzene	77	ND	ND	ND
15	9.0	230	450	260	Naphthalene	ND	ND	ND	ND
16	33	47	100	61	Benzothiophene	ND	ND	ND	ND
17	57	11	ND	63	2-Methylnaphthalene	ND	ND	ND	ND
Pristane	77	11	ND	550	1-Methylnaphthalene	ND	ND	ND	ND
18	24	ND	ND	27	Biphenyl	ND	ND	ND	ND
Phytane	25	ND	ND	250	2,6-Dimethylnaphthalene	ND	ND	ND	ND
19	ND	ND	ND	110	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	ND	12	120	47	Fluorene	ND	ND	ND	ND
21	18	14	ND	23	Dibenzothiophene	ND	ND	ND	ND
22	14	16	ND	59	Phenanthrene	ND	ND	ND	ND
23	49	27	53	73	Anthracene	ND	ND	ND	ND
24	21	28	14	59	1-Methylphenanthrene	51	ND	ND	ND
25	51	32	410	76	Fluoranthene	33	ND	ND	ND
26	24	49	11	55	Pyrene	58	ND	ND	ND
27	100	92	50	100	Benz(a)anthracene	ND	ND	ND	ND
28	ND	72	33	47	Chrysene	ND	ND	ND	ND
29	ND	ND	44	54	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

FALSE BAY

SEDIMENTS

n-Alkanes	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
# carbons	1A	1B					1A	1B			
10	0.25	1.1	ND	ND	ND	o-Xylene	1.2	2.2	ND	ND	ND
11	0.24	0.4	ND	ND	ND	Isopropylbenzene	0.50	0.50	ND	ND	ND
12	ND	ND	1.4	ND	1.2	n-Propylbenzene	0.30	0.50	ND	ND	ND
13	ND	ND	1.6	ND	1.5	Indan	ND	ND	ND	ND	ND
14	ND	0.38	1.6	0.18	1.7	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND	ND
15	1.6	2.0	3.6	5.1	3.1	Naphthalene	2.6	2.7	3.0	ND	ND
16	1.0	1.5	2.6	2.4	1.9	Benzothiophene	ND	ND	ND	ND	ND
17	2.1	2.6	8.7	14	2.3	2-Methylnaphthalene	2.1	2.0	ND	1.2	ND
Pristane	5.7	7.9	13	8.3	2.9	1-Methylnaphthalene	0.80	0.60	ND	0.88	ND
18	1.8	0.70	3.3	4.5	1.5	Biphenyl	ND	ND	ND	ND	0.22
Phytane	0.92	ND	1.3	2.3	1.5	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND
19	2.7	3.9	4.2	3.2	2.2	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND
20	2.0	3.1	5.1	8.2	2.0	Fluorene	2.0	2.0	2.2	5.2	2.1
21	4.1	5.1	10	8.7	2.7	Dibenzothiophene	ND	ND	0.40	ND	3.1
22	8.3	8.3	18	8.2	2.3	Phenanthrene	7.2	7.0	9.9	44	5.3
23	16	15	34	12	4.1	Anthracene	ND	ND	1.9	79	1.5
24	20	17	42	6.3	2.7	1-Methylphenanthrene	1.5	0.60	ND	1.0	ND
25	36	33	62	14	4.5	Fluoranthene	22	19	17	170	7.3
26	20	16	39	5.6	2.3	Pyrene	3.8	4.8	0.83	76	8.4
27	21	19	40	34	6.7	Benz(a)anthracene	5.1	4.5	8.2	58	ND
28	13	12	29	3.7	3.2	Chrysene	ND	ND	5.3	85	2.0
29	9.5	9.5	21	11	7.9	Benzo(e)pyrene	ND	ND	1.7	22	ND
30	5.2	4.5	8.7	3.0	ND	Benzo(a)pyrene	ND	ND	0.34	19	ND
31	7.2	7.9	10	6.7	ND	Perylene	ND	ND	ND	3.0	ND

MUSSELS

n-Alkanes *# carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	ND	180	--	--	o-Xylene	ND	ND	--	--
11	ND	140	--	--	Isopropylbenzene	ND	ND	--	--
12	ND	75	--	--	n-Propylbenzene	20	13	--	--
13	ND	130	--	--	Indan	ND	ND	--	--
14	ND	180	--	--	1,2,3,4-Tetramethylbenzene	ND	ND	--	--
15	100	580	--	--	Naphthalene	ND	ND	--	--
16	ND	140	--	--	Benzothiophene	ND	ND	--	--
17	ND	120	--	--	2-Methylnaphthalene	ND	ND	--	--
Pristane	330	91	--	--	1-Methylnaphthalene	5.3	ND	--	--
18	ND	27	--	--	Biphenyl	ND	ND	--	--
Phytane	ND	61	--	--	2,6-Dimethylnaphthalene	ND	ND	--	--
19	ND	4.6	--	--	2,3,5-Trimethylnaphthalene	ND	ND	--	--
20	ND	ND	--	--	Fluorene	22	ND	--	--
21	7.5	19	--	--	Dibenzothiophene	86	ND	--	--
22	ND	17	--	--	Phenanthrene	520	620	--	--
23	ND	51	--	--	Anthracene	ND	80	--	--
24	ND	86	--	--	1-Methylphenanthrene	ND	64	--	--
25	ND	280	--	--	Fluoranthene	610	760	--	--
26	ND	47	--	--	Pyrene	190	610	--	--
27	ND	52	--	--	Benz(a)anthracene	270	710	--	--
28	ND	ND	--	--	Chrysene	42	540	--	--
29	ND	ND	--	--	Benzo(e)pyrene	ND	ND	--	--
30	ND	ND	--	--	Benzo(a)pyrene	ND	ND	--	--
31	ND	ND	--	--	Perylene	ND	ND	--	--

ANDREWS BAY

SEDIMENTS

n-Alkanes	Spring				Summer		Fall	Winter
# carbons	1A	1B	2A	2B	1	2		
10	4.5	4.8	ND	ND	ND	4.2	ND	ND
11	6.3	4.0	10	8.6	3.5	8.5	ND	ND
12	15	5.3	7.5	7.0	3.3	5.9	2.3	6.2
13	33	5.7	7.9	7.3	4.4	6.0	2.8	6.6
14	49	6.5	9.8	8.9	5.8	8.9	3.7	6.6
15	69	9.4	10	9.3	7.8	11	8.3	7.9
16	7.3	7.6	9.8	8.8	4.3	8.0	6.2	8.2
17	94	12	16	16	7.8	11	10	10
Pristane	260	190	320	280	5.4	14	8.5	7.4
18	95	9.0	7.9	8.3	5.5	7.9	8.8	9.2
Phytane	29	5.8	4.5	6.0	2.2	2.7	3.7	3.4
19	100	13	15	17	7.3	9.5	8.8	11
20	72	6.9	6.0	15	5.9	7.7	11	9.4
21	54	13	16	31	4.9	8.3	11	9.3
22	45	16	31	74	4.8	6.3	[illegible].7	8.2
23	52	23	45	140	5.9	7.8	10	9.1
24	56	25	57	190	3.5	4.9	6.4	6.5
25	83	42	66	250	7.1	9.2	7.9	9.7
26	51	25	43	180	2.3	3.0	4.9	5.3
27	50	28	39	170	5.1	6.6	9.2	8.9
28	34	20	24	130	2.3	3.3	2.4	4.6
29	30	19	21	97	5.9	6.6	7.1	8.1
30	15	9.5	11	66	1.3	ND	1.3	ND
31	20	15	24	74	ND	ND	3.2	ND

Aromatic hydrocarbons	Spring				Summer		Fall	Winter
	1A	1B	2A	2B	1	2		
o-Xylene	ND	3.2	ND	ND	ND	ND	ND	ND
Isopropylbenzene	ND	0.12	3.6	ND	ND	ND	ND	ND
n-Propylbenzene	0.57	0.73	ND	ND	ND	1.2	ND	ND
Indan	0.45	ND	3.5	1.4	ND	0.46	ND	ND
1,2,3,4-Tetramethylbenzene	2.2	0.15	ND	ND	ND	ND	ND	ND
Naphthalene	11	2.0	0.95	2.4	ND	1.3	ND	ND
Benzothiophene	0.70	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	220	3.0	0.56	ND	ND	0.71	ND	ND
1-Methylnaphthalene	120	1.4	1.2	ND	ND	0.87	ND	ND
Biphenyl	1.4	0.72	ND	ND	ND	0.84	ND	ND
2,6-Dimethylnaphthalene	97	2.0	1.6	ND	ND	ND	ND	0.56
2,3,5-Trimethylnaphthalene	7.5	0.34	ND	ND	ND	ND	ND	ND
Fluorene	20	2.0	1.0	ND	ND	1.1	ND	1.0
Dibenzothiophene	1.2	ND	0.69	0.62	ND	ND	ND	ND
Phenanthrene	65	6.4	8.4	7.9	3.7	3.4	ND	3.4
Anthracene	3.1	2.2	ND	1.6	ND	0.74	ND	0.21
1-Methylphenanthrene	6.7	0.15	0.92	0.81	ND	ND	ND	ND
Fluoranthene	1.9	3.9	3.4	4.8	4.6	ND	ND	7.1
Pyrene	3.0	1.0	25	ND	3.0	0.87	ND	6.9
Benz(a)anthracene	1.9	1.2	2.4	ND	ND	ND	ND	ND
Chrysene	15	47	ND	ND	ND	ND	ND	1.0
Benzo(e)pyrene	ND	ND	ND	ND	ND	ND	ND	0.36
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	0.40
Perylene	ND	ND	ND	ND	ND	ND	ND	ND

WESTCOTT BAY

MUSSELS

n-Alkanes *# carbons*	Spring	Summer	Fall	Winter
10	ND	ND	ND	ND
11	ND	ND	ND	ND
12	ND	26	ND	ND
13	ND	ND	20	ND
14	ND	54	95	62
15	43	200	230	260
16	36	64	110	47
17	ND	55	44	110
Pristane	ND	ND	ND	68
18	ND	ND	ND	ND
Phytane	ND	ND	ND	ND
19	ND	ND	ND	ND
20	ND	ND	ND	ND
21	150	ND	240	ND
22	ND	ND	ND	ND
23	ND	ND	ND	ND
24	ND	ND	ND	ND
25	ND	11	ND	63
26	ND	ND	14	ND
27	ND	42	ND	ND
28	ND	ND	ND	ND
29	ND	ND	49	ND
30	ND	ND	ND	ND
31	ND	ND	ND	ND

Aromatic hydrocarbons	Spring	Summer	Fall	Winter
o-Xylene	ND	ND	ND	ND
Isopropylbenzene	ND	ND	ND	ND
n-Propylbenzene	ND	ND	ND	ND
Indan	ND	ND	ND	ND
1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
Naphthalene	ND	ND	ND	ND
Benzothiophene	ND	ND	ND	ND
2-Methylnaphthalene	ND	ND	ND	ND
1-Methylnaphthalene	ND	ND	ND	ND
Biphenyl	ND	ND	ND	ND
2,6-Dimethylnaphthalene	ND	ND	ND	ND
2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND
Dibenzothiophene	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND
1-Methylphenanthrene	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND
Pyrene	24	ND	ND	ND
Benz(a)anthracene	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND
Benzo(e)pyrene	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND
Perylene	ND	ND	ND	ND

LEGOE BAY/LUMMI ISLAND

MUSSELS

n-Alkanes # carbons	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	ND	260	940	ND	o-Xylene	ND	34	ND	ND
11	ND	250	850	ND	Isopropylbenzene	ND	ND	ND	ND
12	ND	220	520	ND	n-Propylbenzene	ND	ND	ND	ND
13	ND	67	110	46	Indan	ND	ND	ND	ND
14	ND	52	130	150	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	92	150	430	350	Naphthalene	ND	18	ND	ND
16	ND	73	65	100	Benzothiophene	ND	ND	ND	ND
17	ND	320	130	130	2-Methylnaphthalene	ND	ND	ND	ND
Pristane	230	250	840	230	1-Methylnaphthalene	ND	ND	110	ND
18	ND	ND	9.9	ND	Biphenyl	ND	ND	ND	ND
Phytane	ND	ND	46	ND	2,6-Dimethylnaphthalene	ND	ND	ND	ND
19	ND	ND	ND	ND	2,3,5-Trimethylnaphthalene	ND	ND	ND	50
20	ND	ND	28	ND	Fluorene	15	ND	ND	ND
21	ND	170	28	ND	Dibenzothiophene	ND	ND	ND	ND
22	ND	ND	30	ND	Phenanthrene	180	ND	ND	240
23	ND	ND	53	ND	Anthracene	ND	ND	ND	30
24	38	ND	26	110	1-Methylphenanthrene	54	ND	ND	ND
25	ND	ND	170	ND	Fluoranthene	200	ND	ND	92
26	ND	ND	24	110	Pyrene	95	ND	ND	ND
27	ND	13	160	ND	Benz(a)anthracene	42	ND	ND	230
28	ND	ND	22	ND	Chrysene	ND	ND	ND	130
29	ND	ND	860	230	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

CAPE GEORGE

SEDIMENTS

n-Alkanes *# carbons*	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
	1A	1B					1A	1B			
10	ND	ND	0.4	ND	ND	o-Xylene	ND	ND	ND	ND	ND
11	ND	ND	ND	ND	ND	Isopropylbenzene	ND	ND	ND	ND	ND
12	ND	ND	ND	ND	1.4	n-Propylbenzene	ND	0.14	ND	ND	ND
13	ND	ND	ND	ND	1.6	Indan	ND	0.66	ND	ND	ND
14	ND	ND	ND	ND	2.1	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND	ND
15	0.6	ND	2.0	ND	8.5	Naphthalene	ND	ND	1.1	ND	ND
16	0.2	ND	ND	ND	1.6	Benzothiophene	ND	ND	ND	ND	ND
17	1.5	0.70	0.57	19	7.9	2-Methylnaphthalene	ND	0.11	ND	ND	ND
Pristane	ND	ND	4.0	ND	3.1	1-Methylnaphthalene	ND	ND	ND	ND	ND
18	0.70	ND	ND	ND	0.010	Biphenyl	ND	ND	ND	ND	ND
Phytane	ND	ND	ND	ND	1.4	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND
19	1.5	0.80	ND	29	2.6	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND
20	0.50	0.60	0.55	4.9	1.7	Fluorene	ND	ND	ND	ND	ND
21	0.90	0.70	2.4	8.5	2.8	Dibenzothiophene	ND	0.18	ND	ND	ND
22	0.72	0.92	3.3	2.2	2.3	Phenanthrene	0.37	0.54	ND	ND	ND
23	1.1	1.7	7.5	5.7	4.2	Anthracene	ND	ND	ND	ND	ND
24	0.31	1.5	7.4	3.0	2.5	1-Methylphenanthrene	ND	ND	4.3	ND	ND
25	4.3	3.7	8.4	8.1	5.6	Fluoranthene	ND	ND	ND	ND	1.8
26	ND	1.4	6.6	2.7	3.2	Pyrene	0.39	0.51	ND	ND	3.0
27	2.6	3.5	8.3	13	13	Benz(a)anthracene	ND	ND	ND	ND	12
28	1.1	2.1	3.5	2.1	4.3	Chrysene	1.2	1.4	ND	ND	3.0
29	3.0	2.7	5.6	8.7	6.4	Benzo(e)pyrene	ND	ND	ND	ND	ND
30	ND	ND	ND	ND	0.52	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	ND	ND	ND	6.7	9.3	Perylene	ND	ND	ND	ND	ND

MUSSELS

n-Alkanes *# carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	ND	150	ND	ND	o-Xylene	ND	22	ND	ND
11	ND	70	ND	ND	Isopropylbenzene	ND	ND	ND	ND
12	ND	110	ND	ND	n-Propylbenzene	ND	63	28	ND
13	ND	74	ND	57	Indan	96	4.0	ND	ND
14	ND	120	7.3	150	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	46	370	240	290	Naphthalene	ND	18	ND	24
16	ND	100	ND	83	Benzothiophene	ND	ND	ND	ND
17	ND	370	ND	110	2-Methylnaphthalene	ND	ND	ND	ND
Pristane	140	110	ND	86	1-Methylnaphthalene	ND	ND	ND	ND
18	ND	28	ND	ND	Biphenyl	ND	ND	ND	ND
Phytane	ND	23	ND	ND	2,6-Dimethylnaphthalene	ND	ND	ND	ND
19	ND	54	ND	ND	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	ND	ND	ND	ND	Fluorene	ND	ND	ND	ND
21	52	17	ND	ND	Dibenzothiophene	ND	51	ND	ND
22	ND	15	ND	ND	Phenanthrene	88	ND	160	ND
23	ND	23	ND	ND	Anthracene	ND	ND	ND	ND
24	ND	72	ND	ND	1-Methylphenanthrene	ND	86	ND	ND
25	ND	99	ND	ND	Fluoranthene	ND	ND	150	110
26	ND	44	ND	ND	Pyrene	110	ND	62	ND
27	ND	56	ND	98	Benz(a)anthracene	ND	ND	ND	ND
28	ND	ND	ND	ND	Chrysene	ND	ND	ND	ND
29	ND	ND	ND	ND	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

DUNGENESS/THREE CRABS

SEDIMENTS

n-Alkanes # *carbons*	Spring			Summer		Fall	Winter	Aromatic hydrocarbons	Spring			Summer		Fall	Winter
	1	2A	2B	1	2				1	2A	2B	1	2		
10	ND	ND	ND	1.7	0.5	ND	ND	o-Xylene	ND	ND	ND	ND	ND	ND	ND
11	3.4	2.0	ND	5.9	4.7	ND	ND	Isopropylbenzene	3.4	0.02	ND	1.9	ND	ND	ND
12	6.3	5.3	3.0	4.4	3.7	6.9	7.7	n-Propylbenzene	ND	ND	ND	1.2	0.92	ND	ND
13	8.5	8.5	4.7	7.1	7.0	7.0	9.5	Indan	1.6	3.8	1.2	0.63	4.2	ND	ND
14	11	4.3	7.1	8.0	8.1	7.5	10	1,2,3,4-Tetramethylbenzene	ND	ND	ND	0.35	ND	ND	ND
15	19	27	12	13	14	1.3	21	Naphthalene	4.6	2.4	1.8	1.5	2.1	ND	ND
16	9.8	8.9	7.6	6.9	6.1	5.9	13	Benzothiophene	ND	ND	ND	ND	ND	ND	ND
17	17	13	11	8.9	9.0	6.1	18	2-Methylnaphthalene	1.0	ND	0.62	4.5	2.5	ND	ND
Pristane	29	11	13	20	22	12	32	1-Methylnaphthalene	1.3	1.8	1.2	3.3	2.3	ND	ND
18	8.6	9.2	8.8	6.8	6.6	5.7	13	Biphenyl	ND	ND	ND	0.073	ND	ND	1.1
Phytane	4.2	3.9	4.3	3.2	3.3	2.7	9.8	2,6-Dimethylnaphthalene	ND	ND	ND	2.2	1.8	ND	2.2
19	17	16	15	11	11	8.1	15	2,3,5-Trimethylnaphthalene	ND	ND	ND	0.30	0.40	ND	2.3
20	13	9.3	11	7.2	7.1	7.2	13	Fluorene	ND	ND	ND	0.18	0.72	ND	ND
21	17	17	23	9.9	11	10	17	Dibenzothiophene	0.71	ND	ND	ND	ND	ND	ND
22	21	20	45	7.7	7.1	11	13	Phenanthrene	7.8	6.7	6.2	5.8	7.1	ND	9.1
23	41	38	85	15	16	24	32	Anthracene	ND	ND	ND	ND	1.1	ND	0.74
24	30	28	92	7.6	7.7	16	14	1-Methylphenanthrene	1.8	5.7	1.3	0.43	0.24	ND	1.1
25	100	100	180	33	36	67	81	Fluoranthene	1.5	4.8	2.9	4.7	ND	ND	4.8
26	19	27	89	6.9	7.3	20	15	Pyrene	13	11	9.2	0.47	ND	ND	7.3
27	140	120	170	58	65	150	160	Benz(a)anthracene	ND	ND	ND	ND	ND	ND	ND
28	17	27	70	7.8	8.4	15	18	Chrysene	33	27	26	ND	ND	ND	ND
29	130	100	120	46	49	120	130	Benzo(e)pyrene	ND	ND	ND	ND	ND	ND	2.2
30	7.0	16	35	6.0	5.3	18	15	Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND
31	88	80	90	35	37	99	130	Perylene	ND	ND	ND	ND	ND	ND	1.1

MUSSELS

n-Alkanes # *carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	13	ND	31	ND	o-Xylene	ND	ND	ND	ND
11	14	5.3	34	ND	Isopropylbenzene	ND	ND	ND	ND
12	23	43	32	ND	n-Propylbenzene	ND	39	ND	ND
13	42	31	24	ND	Indan	ND	ND	ND	ND
14	5.4	120	160	55	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	310	250	260	300	Naphthalene	ND	ND	ND	ND
16	94	61	100	100	Benzothiophene	ND	ND	ND	ND
17	71	67	130	160	2-Methylnaphthalene	ND	ND	ND	ND
Pristane	71	ND	11	54	1-Methylnaphthalene	ND	ND	ND	ND
18	19	ND	19	ND	Biphenyl	ND	ND	ND	ND
Phytane	ND	ND	ND	ND	2,6-Dimethylnaphthalene	86	34	ND	ND
19	3.0	ND	20	ND	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	14	ND	ND	ND	Fluorene	ND	ND	ND	ND
21	36	ND	ND	ND	Dibenzothiophene	ND	48	ND	ND
22	22	ND	ND	ND	Phenanthrene	ND	ND	ND	ND
23	54	ND	25	ND	Anthracene	ND	ND	ND	ND
24	62	ND	ND	ND	1-Methylphenanthrene	ND	80	ND	ND
25	240	23	53	ND	Fluoranthene	ND	ND	ND	290
26	74	ND	ND	ND	Pyrene	ND	ND	ND	690
27	240	63	120	89	Benz(a)anthracene	ND	ND	ND	ND
28	76	ND	ND	ND	Chrysene	ND	ND	ND	ND
29	260	ND	ND	ND	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	240	ND	ND	ND	Perylene	ND	ND	ND	ND

DUNGENESS SPIT

SEDIMENTS

n-Alkanes	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
# *carbons*	1A	1B					1A	1B			
10	ND	ND	ND	ND	ND	o-Xylene	ND	ND	ND	ND	ND
11	ND	ND	2.0	ND	ND	Isopropylbenzene	ND	ND	1.1	ND	ND
12	0.50	ND	2.4	ND	3.0	n-Propylbenzene	ND	0.10	0.51	ND	ND
13	0.40	ND	2.2	ND	2.6	Indan	0.82	ND	ND	ND	ND
14	1.1	ND	2.0	ND	2.8	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND	ND
15	1.5	0.30	2.3	ND	2.7	Naphthalene	ND	ND	0.57	ND	ND
16	1.6	0.40	2.3	ND	2.5	Benzothiophene	ND	ND	ND	ND	ND
17	2.0	0.90	2.9	ND	2.3	2-Methylnaphthalene	0.41	ND	ND	ND	ND
Pristane	0.90	ND	1.5	ND	1.9	1-Methylnaphthalene	ND	ND	ND	ND	ND
18	2.0	1.4	2.3	ND	2.4	Biphenyl	ND	ND	0.18	ND	ND
Phytane	ND	ND	0.84	ND	1.2	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND
19	2.1	1.4	2.1	0.33	2.9	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND
20	2.7	0.80	2.3	0.57	2.1	Fluorene	ND	ND	ND	ND	ND
21	2.2	1.5	2.7	1.0	2.2	Dibenzothiophene	ND	ND	ND	ND	ND
22	1.8	1.2	2.6	1.4	2.2	Phenanthrene	1.5	1.4	1.3	ND	ND
23	1.6	1.5	5.3	1.9	3.5	Anthracene	ND	ND	ND	ND	ND
24	1.4	1.4	5.3	1.7	2.8	1-Methylphenanthrene	ND	ND	0.87	ND	ND
25	1.8	2.0	4.9	2.2	2.9	Fluoranthene	0.45	0.29	0.13	ND	ND
26	0.71	1.1	7.8	1.5	2.0	Pyrene	0.28	ND	ND	ND	ND
27	1.3	1.8	8.5	3.1	3.5	Benz(a)anthracene	ND	ND	ND	ND	ND
28	2.0	1.9	5.4	0.93	1.9	Chrysene	ND	ND	ND	ND	ND
29	0.80	ND	4.8	1.9	3.3	Benzo(e)pyrene	ND	ND	ND	ND	ND
30	ND	ND	5.9	ND	1.4	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	ND	ND	4.6	ND	4.2	Perylene	ND	ND	ND	ND	ND

EDIZ HOOK

SEDIMENTS

n-Alkanes	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
# carbons	1A	1B					1A	1B			
10	ND	ND	0.9	ND	ND	o-Xylene	3.1	1.4	ND	ND	ND
11	1.9	1.4	2.4	ND	ND	Isopropylbenzene	ND	ND	1.3	ND	ND
12	5.5	4.7	3.4	6.6	5.3	n-Propylbenzene	ND	ND	0.67	ND	ND
13	13	11	6.8	9.4	9.4	Indan	0.34	0.09	ND	ND	ND
14	21	22	11	14	14	1,2,3,4-Tetramethylbenzene	0.32	0.10	0.094	ND	ND
15	29	23	16	17	17	Naphthalene	3.0	2.7	1.5	ND	ND
16	25	16	16	13	14	Benzothiophene	ND	ND	ND	ND	ND
17	27	18	22	14	16	2-Methylnaphthalene	5.0	3.8	1.8	ND	ND
Pristane	40	25	29	20	27	1-Methylnaphthalene	1.6	1.2	0.64	ND	ND
18	31	19	20	13	17	Biphenyl	0.74	0.5	ND	ND	ND
Phytane	27	18	20	13	18	2,6-Dimethylnaphthalene	2.4	1.6	0.49	ND	ND
19	42	28	26	17	22	2,3,5-Trimethylnaphthalene	1.7	ND	ND	ND	ND
20	29	20	21	14	17	Fluorene	1.0	0.89	ND	ND	1.1
21	24	18	14	10	13	Dibenzothiophene	2.5	2.1	ND	ND	1.5
22	21	17	12	9.0	11	Phenanthrene	7.1	4.5	3.6	ND	4.9
23	16	13	12	9.3	11	Anthracene	0.54	0.54	ND	ND	ND
24	11	11	5.9	7.6	7.9	1-Methylphenanthrene	0.56	ND	0.66	ND	ND
25	22	22	4.0	6.5	9.7	Fluoranthene	0.58	1.5	3.1	ND	5.3
26	6.0	6.0	1.3	4.8	4.4	Pyrene	4.1	3.9	3.5	ND	7.8
27	10	10	1.4	6.0	6.0	Benz(a)anthracene	0.61	0.61	ND	ND	ND
28	13	17	5.4	8.4	7.4	Chrysene	4.8	3.4	ND	ND	0.83
29	17	16	11	10	8.3	Benzo(e)pyrene	ND	ND	ND	ND	ND
30	ND	ND	18	1.8	1.6	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	5.0	4.4	22	4.1	4.6	Perylene	ND	ND	ND	ND	ND

MUSSELS

n-Alkanes *# carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	55	290	370	560	o-Xylene	ND	41	ND	ND
11	180	260	530	5000	Isopropylbenzene	ND	ND	ND	ND
12	210	200	590	7800	n-Propylbenzene	ND	56	ND	ND
13	63	65	180	5500	Indan	ND	99	ND	ND
14	ND	51	360	1600	1,2,3,4-Tetramethylbenzene	150	ND	ND	ND
15	270	190	590	770	Naphthalene	ND	42	7.0	ND
16	22	69	68	27	Benzothiophene	ND	ND	ND	ND
17	580	350	200	230	2-Methylnaphthalene	ND	ND	21	ND
Pristane	630	240	540	2600	1-Methylnaphthalene	ND	ND	4300	86
18	ND	ND	77	ND	Biphenyl	ND	ND	ND	ND
Phytane	170	50	150	1500	2,6-Dimethylnaphthalene	ND	ND	ND	42
19	72	150	35	510	2,3,5-Trimethylnaphthalene	ND	ND	ND	40
20	130	ND	180	260	Fluorene	180	ND	ND	160
21	57	ND	170	420	Dibenzothiophene	68	ND	ND	110
22	180	ND	230	450	Phenanthrene	2600	50	65	1400
23	23	ND	280	370	Anthracene	ND	ND	ND	200
24	12	ND	190	230	1-Methylphenanthrene	470	ND	190	120
25	ND	ND	170	150	Fluoranthene	4000	320	8.8	ND
26	ND	ND	130	110	Pyrene	300	610	ND	4100
27	ND	ND	200	ND	Benz(a)anthracene	540	ND	ND	1600
28	ND	ND	120	ND	Chrysene	ND	ND	ND	730
29	ND	ND	47	ND	Benzo(e)pyrene	ND	ND	ND	130
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	100
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

TONGUE POINT/CRESCENT BAY

SEDIMENTS

n-Alkanes	Spring			Summer		Fall	Winter	Aromatic hydrocarbons	Spring			Summer		Fall	Winter
# *carbons*	1	2A	2B	1	2				1	2A	2B	1	2		
10	ND	91	100	0.8	ND	ND	ND	o-Xylene	ND	ND	ND	ND	ND	ND	ND
11	ND	24	29	0.9	ND	ND	ND	Isopropylbenzene	ND	ND	ND	2.3	ND	ND	ND
12	1.1	ND	ND	0.3	ND	2.1	0.81	n-Propylbenzene	ND	ND	ND	0.97	1.5	ND	ND
13	0.82	ND	ND	0.1	ND	1.8	0.89	Indan	1.4	1.2	2.2	ND	0.61	ND	ND
14	1.5	ND	ND	2.1	2.4	1.9	1.5	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND	ND	ND	ND
15	2.1	1.4	1.8	3.9	4.0	2.6	2.5	Naphthalene	ND	ND	ND	1.0	2.8	ND	ND
16	2.2	1.6	2.1	1.0	1.4	2.4	3.0	Benzothiophene	ND	ND	ND	ND	ND	ND	ND
17	4.1	2.5	3.2	2.5	2.4	2.4	4.4	2-Methylnaphthalene	ND	ND	ND	0.49	0.65	ND	ND
Pristane	2.8	2.2	5.1	7.7	2.0	3.6	5.6	1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND
18	2.5	1.7	2.2	2.3	2.5	2.7	3.7	Biphenyl	ND	ND	ND	ND	ND	ND	0.15
Phytane	2.8	1.8	2.3	2.1	2.2	1.5	2.1	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND
19	7.8	3.5	4.8	5.5	5.4	4.2	4.4	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND
20	ND	2.9	3.9	3.8	4.0	4.6	4.1	Fluorene	ND	ND	ND	ND	ND	ND	0.41
21	9.6	5.4	8.2	6.4	6.2	6.5	5.8	Dibenzothiophene	ND	ND	ND	ND	ND	ND	ND
22	19	7.7	14	4.4	4.0	6.7	4.7	Phenanthrene	2.0	ND	ND	1.7	ND	ND	1.7
23	35	14	27	8.1	8.7	12	7.9	Anthracene	ND	ND	ND	ND	ND	ND	ND
24	42	14	31	5.2	6.0	11	5.5	1-Methylphenanthrene	ND	ND	ND	0.17	ND	ND	ND
25	57	25	50	14	11	27	14	Fluoranthene	ND	0.56	0.79	4.5	13	ND	2.3
26	32	13	31	4.9	5.6	13	6.2	Pyrene	30	52	77	ND	ND	ND	2.6
27	35	17	34	12	13	28	17	Benz(a)anthracene	ND	ND	ND	ND	ND	ND	ND
28	21	10	23	4.1	5.0	20	8.4	Chrysene	2.3	ND	ND	ND	ND	ND	0.57
29	23	11	23	11	12	23	19	Benzo(e)pyrene	ND	ND	ND	ND	ND	ND	ND
30	11	ND	ND	2.6	1.4	8.0	13	Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND
31	22	ND	ND	7.6	6.4	24	29	Perylene	ND	ND	ND	ND	ND	ND	ND

MUSSELS

n-Alkanes # *carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	ND	ND	ND	ND	o-Xylene	ND	ND	ND	ND
11	ND	ND	ND	ND	Isopropylbenzene	ND	ND	ND	ND
12	ND	ND	ND	ND	n-Propylbenzene	ND	ND	ND	ND
13	ND	ND	16	ND	Indan	ND	ND	ND	ND
14	ND	ND	26	ND	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	ND	180	160	170	Naphthalene	ND	ND	13	ND
16	ND	ND	50	ND	Benzothiophene	ND	ND	ND	ND
17	ND	230	64	150	2-Methylnaphthalene	ND	ND	ND	ND
Pristane	ND	180	490	180	1-Methylnaphthalene	ND	ND	ND	ND
18	ND	ND	ND	ND	Biphenyl	ND	ND	ND	ND
Phytane	ND	ND	ND	ND	2,6-Dimethylnaphthalene	ND	ND	ND	ND
19	ND	ND	ND	ND	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	ND	ND	ND	ND	Fluorene	ND	ND	ND	ND
21	ND	ND	17	ND	Dibenzothiophene	ND	ND	ND	ND
22	ND	ND	24	ND	Phenanthrene	ND	ND	ND	ND
23	ND	70	47	ND	Anthracene	ND	ND	ND	ND
24	ND	76	35	ND	1-Methylphenanthrene	ND	ND	ND	ND
25	ND	63	93	ND	Fluoranthene	ND	ND	ND	ND
26	ND	83	30	ND	Pyrene	ND	ND	25	ND
27	ND	130	100	ND	Benz(a)anthracene	ND	ND	ND	ND
28	ND	92	17	ND	Chrysene	ND	ND	ND	ND
29	ND	67	77	ND	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

DEEP CREEK BEACH

S E D I M E N T S

n-Alkanes	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
# carbons	1A	1B					1A	1B			
10	ND	ND	ND	ND	ND	o-Xylene	ND	ND	ND	ND	ND
11	ND	ND	2.3	ND	ND	Isopropylbenzene	ND	ND	0.73	ND	ND
12	0.40	1.5	3.0	ND	3.1	n-Propylbenzene	0.66	0.12	1.1	ND	ND
13	2.5	3.6	3.6	ND	3.9	Indan	0.37	0.08	0.25	ND	ND
14	3.6	4.9	4.5	ND	4.9	1,2,3,4-Tetramethylbenzene	0.18	0.37	0.25	ND	ND
15	6.1	8.3	4.7	0.47	5.9	Naphthalene	1.8	0.90	1.8	ND	ND
16	6.2	8.1	5.5	0.98	6.7	Benzothiophene	ND	ND	ND	ND	ND
17	8.6	12	7.3	4.1	8.3	2-Methylnaphthalene	3.7	3.4	1.6	2.1	ND
Pristane	39	50	20	13	28	1-Methylnaphthalene	3.1	2.9	1.0	1.3	ND
18	8.6	12	5.2	4.8	7.5	Biphenyl	0.10	0.70	ND	ND	ND
Phytane	6.8	9.1	2.2	2.2	5.3	2,6-Dimethylnaphthalene	1.7	1.5	ND	ND	ND
19	15	20	7.1	5.1	8.9	2,3,5-Trimethylnaphthalene	3.0	1.8	ND	ND	ND
20	11	15	7.2	5.8	8.7	Fluorene	ND	0.06	ND	ND	ND
21	21	31	9.6	5.2	11	Dibenzothiophene	ND	ND	ND	ND	0.79
22	36	59	6.3	6.5	11	Phenanthrene	4.4	3.7	2.4	2.9	2.5
23	62	100	6.4	9.2	15	Anthracene	0.03	ND	ND	ND	ND
24	80	130	4.1	6.9	14	1-Methylphenanthrene	1.7	1.3	1.7	1.4	ND
25	110	180	13	9.7	19	Fluoranthene	8.5	6.3	1.2	ND	1.4
26	75	120	3.3	6.3	13	Pyrene	15	1.6	0.32	ND	1.4
27	75	110	5.6	11	23	Benz(a)anthracene	ND	0.31	ND	ND	ND
28	54	81	4.7	4.5	12	Chrysene	8.8	8.3	ND	ND	ND
29	48	66	8.2	7.4	18	Benzo(e)pyrene	ND	ND	ND	ND	ND
30	22	31	6.3	2.4	8.9	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	30	39	8.2	4.8	15	Perylene	ND	ND	ND	ND	ND

DEEP CREEK

M U S S E L S

n-Alkanes *# carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	7.8	ND	ND	ND	o-Xylene	ND	32	ND	ND
11	ND	ND	ND	ND	Isopropylbenzene	ND	ND	ND	ND
12	ND	38	43	ND	n-Propylbenzene	ND	110	ND	ND
13	ND	40	40	ND	Indan	ND	15	ND	ND
14	34	99	170	120	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	ND	310	420	250	Naphthalene	ND	ND	ND	ND
16	ND	93	100	68	Benzothiophene	ND	ND	ND	ND
17	140	240	160	160	2-Methylnaphthalene	ND	ND	ND	ND
Pristane	8.8	31	200	ND	1-Methylnaphthalene	ND	ND	ND	ND
18	45	ND	21	ND	Biphenyl	ND	ND	ND	ND
Phytane	31	ND	ND	ND	2,6-Dimethylnaphthalene	ND	ND	ND	ND
19	33	ND	26	ND	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	55	ND	23	ND	Fluorene	ND	ND	ND	ND
21	68	ND	80	ND	Dibenzothiophene	ND	ND	ND	ND
22	62	ND	72	ND	Phenanthrene	ND	ND	ND	ND
23	74	50	130	ND	Anthracene	ND	ND	ND	ND
24	57	48	120	ND	1-Methylphenanthrene	ND	ND	ND	ND
25	130	37	320	ND	Fluoranthene	ND	ND	ND	120
26	53	52	84	ND	Pyrene	ND	ND	ND	ND
27	ND	63	200	90	Benz(a)anthracene	ND	ND	ND	ND
28	ND	23	37	ND	Chrysene	ND	ND	ND	ND
29	ND	ND	97	ND	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

PILLAR POINT

SEDIMENTS

n-Alkanes # *carbons*	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
	1A	1B					1A	1B			
10	0.78	1.1	3.4	ND	ND	o--Xylene	0.90	0.20	ND	ND	ND
11	0.30	1.4	ND	ND	ND	Isopropylbenzene	ND	ND	ND	ND	ND
12	ND	0.43	1.1	0.77	1.6	n-Propylbenzene	ND	ND	ND	ND	ND
13	ND	0.77	1.5	0.79	1.9	Indan	ND	ND	ND	ND	ND
14	0.86	1.8	2.6	5.2	2.6	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND	ND
15	2.6	3.3	4.5	8.7	4.0	Naphthalene	ND	ND	1.7	ND	ND
16	3.0	3.3	3.1	6.7	3.9	Benzothiophene	ND	ND	ND	ND	ND
17	3.9	5.0	1.0	5.7	ND	2-Methylnaphthalene	0.90	0.50	0.18	ND	ND
Pristane	74	69	82	34	ND	1-Methylnaphthalene	0.70	0.50	0.63	ND	ND
18	4.0	4.7	2.5	7.5	5.1	Biphenyl	ND	ND	ND	ND	ND
Phytane	ND	ND	3.7	7.6	3.9	2,6-Dimethylnaphthalene	0.80	0.80	ND	ND	ND
19	4.4	7.7	6.2	13	5.3	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND
20	4.4	5.7	6.2	9.0	5.4	Fluorene	ND	ND	ND	ND	0.49
21	7.6	11	8.1	11	6.8	Dibenzothiophene	ND	ND	1.7	ND	ND
22	8.9	20	9.3	11	6.3	Phenanthrene	0.30	0.30	ND	ND	2.4
23	17	38	15	18	9.9	Anthracene	ND	ND	ND	ND	ND
24	16	43	15	11	7.5	1-Methylphenanthrene	ND	ND	ND	ND	0.25
25	36	73	30	24	15	Fluoranthene	12	12	2.2	ND	6.6
26	16	41	13	13	8.2	Pyrene	0.50	3.5	ND	ND	3.1
27	27	48	22	31	21	Benz(a)anthracene	3.8	3.4	ND	ND	ND
28	14	28	14	3.4	9.7	Chrysene	ND	0.2	ND	ND	ND
29	20	29	20	19	20	Benzo(e)pyrene	ND	ND	ND	ND	ND
30	6.8	1.1	15	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	22	26	22	ND	15	Perylene	ND	ND	0.94	ND	ND

MUSSELS

n-Alkanes # *carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	11	68	ND	ND	o-Xylene	ND	ND	ND	ND
11	ND	24	ND	ND	Isopropylbenzene	ND	ND	ND	ND
12	ND	ND	ND	ND	n-Propylbenzene	ND	ND	ND	ND
13	15	ND	ND	ND	Indan	ND	ND	ND	ND
14	30	23	19	ND	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	210	210	160	65	Naphthalene	ND	ND	ND	ND
16	74	44	51	ND	Benzothiophene	ND	ND	ND	ND
17	57	43	49	55	2-Methylnaphthalene	ND	ND	ND	ND
Pristane	520	3500	ND	62	1-Methylnaphthalene	ND	ND	ND	ND
18	18	ND	ND	ND	Biphenyl	ND	ND	ND	ND
Phytane	27	ND	29	ND	2,6-Dimethylnaphthalene	ND	ND	ND	ND
19	1.9	ND	ND	ND	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	77	ND	ND	ND	Fluorene	ND	ND	ND	ND
21	30	ND	ND	ND	Dibenzothiophene	ND	ND	ND	ND
22	32	ND	26	ND	Phenanthrene	ND	ND	ND	49
23	46	42	ND	ND	Anthracene	ND	ND	ND	ND
24	36	45	21	ND	1-Methylphenanthrene	ND	ND	ND	ND
25	110	47	150	ND	Fluoranthene	ND	ND	ND	140
26	35	65	14	ND	Pyrene	35	ND	ND	52
27	99	130	87	ND	Benz(a)anthracene	ND	ND	ND	66
28	34	ND	ND	ND	Chrysene	88	ND	ND	32
29	40	ND	ND	ND	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	ND	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	ND	ND	ND	Perylene	ND	ND	ND	ND

KYDAKA POINT

SEDIMENTS

n-Alkanes	Spring		Summer	Fall	Winter	Aromatic hydrocarbons	Spring		Summer	Fall	Winter
# *carbons*	1A	1B					1A	1B			
10	ND	ND	0.6	ND	ND	o-Xylene	ND	ND	ND	ND	ND
11	3.4	ND	2.3	ND	ND	Isopropylbenzene	0.02	ND	ND	ND	ND
12	12	7.2	3.0	12	11	n-Propylbenzene	1.1	0.88	1.1	ND	ND
13	12	8.0	4.3	12	13	Indan	ND	ND	ND	ND	ND
14	15	9.7	5.4	12	3.2	1,2,3,4-Tetramethylbenzene	0.14	0.13	ND	ND	ND
15	16	11	5.0	12	15	Naphthalene	3.1	2.9	2.0	ND	ND
16	16	11	5.1	9.6	16	Benzothiophene	ND	ND	ND	ND	ND
17	16	10	6.2	10	17	2-Methylnaphthalene	12	11	1.9	3.9	ND
Pristane	13	9.6	10	13	22	1-Methylnaphthalene	8.4	7.5	1.5	4.0	ND
18	19	13	4.6	10	16	Biphenyl	4.4	2.8	0.47	1.3	2.7
Phytane	6.1	3.9	1.7	3.3	3.3	2,6-Dimethylnaphthalene	9.2	9.0	1.6	4.5	6.5
19	25	16	7.8	14	17	2,3,5-Trimethylnaphthalene	4.8	4.6	0.37	ND	3.0
20	20	12	7.1	15	17	Fluorene	1.5	1.6	ND	ND	0.58
21	27	17	8.7	18	19	Dibenzothiophene	2.7	ND	ND	ND	ND
22	28	17	7.9	23	19	Phenanthrene	24	23	0.58	13	13
23	35	20	8.7	33	23	Anthracene	0.38	0.26	ND	ND	ND
24	34	18	8.4	36	20	1-Methylphenanthrene	1.0	0.90	0.39	1.2	2.4
25	52	29	12	46	23	Fluoranthene	1.6	1.1	ND	1.7	1.8
26	31	18	6.7	44	20	Pyrene	4.3	4.0	ND	ND	3.0
27	40	24	9.9	64	25	Benz(a)anthracene	0.16	0.06	ND	ND	ND
28	31	19	10	23	12	Chrysene	20	19	ND	3.8	3.0
29	34	22	8.7	50	16	Benzo(e)pyrene	ND	ND	ND	ND	ND
30	16	9.7	7.5	29	16	Benzo(a)pyrene	ND	ND	ND	ND	ND
31	25	16	10	37	22	Perylene	ND	ND	ND	ND	ND

MUSSELS

n-Alkanes # *carbons*	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	20	180	--	ND	o-Xylene	ND	37	--	ND
11	20	200	--	ND	Isopropylbenzene	ND	ND	--	ND
12	ND	170	--	ND	n-Propylbenzene	ND	ND	--	ND
13	ND	70	--	130	Indan	ND	120	--	ND
14	13	55	--	93	1,2,3,4-Tetramethylbenzene	ND	ND	--	ND
15	ND	410	--	420	Naphthalene	ND	28	--	ND
16	ND	77	--	110	Benzothiophene	ND	ND	--	ND
17	ND	65	--	380	2-Methylnaphthalene	ND	ND	--	ND
Pristane	ND	420	--	170	1-Methylnaphthalene	ND	ND	--	ND
18	ND	ND	--	ND	Biphenyl	ND	ND	--	ND
Phytane	ND	ND	--	ND	2,6-Dimethylnaphthalene	ND	ND	--	ND
19	ND	ND	--	ND	2,3,5-Trimethylnaphthalene	ND	ND	--	ND
20	16	ND	--	ND	Fluorene	ND	ND	--	ND
21	27	ND	--	ND	Dibenzothiophene	ND	ND	--	ND
22	20	ND	--	ND	Phenanthrene	ND	ND	--	ND
23	50	ND	--	71	Anthracene	ND	ND	--	ND
24	37	ND	--	550	1-Methylphenanthrene	ND	ND	--	ND
25	120	ND	--	420	Fluoranthene	ND	ND	--	23
26	ND	ND	--	370	Pyrene	210	ND	--	47
27	170	22	--	930	Benz(a)anthracene	ND	ND	--	ND
28	ND	ND	--	670	Chrysene	42	ND	--	ND
29	ND	ND	--	660	Benzo(e)pyrene	ND	ND	--	ND
30	ND	ND	--	490	Benzo(a)pyrene	ND	ND	--	ND
31	ND	ND	--	350	Perylene	ND	ND	--	ND

BAADAH POINT

SEDIMENTS

n-Alkanes # carbons	Spring		Summer		Fall	Winter	Aromatic hydrocarbons	Spring		Summer		Fall	Winter
	1	2	1	2				1	2	1	2		
10	ND	ND	4.0	2.8	ND	ND	o-Xylene	ND	ND	ND	ND	ND	ND
11	6.1	ND	4.5	5.8	ND	ND	Isopropylbenzene	ND	0.25	ND	ND	ND	ND
12	5.7	2.9	4.6	4.3	3.0	3.8	n-Propylbenzene	ND	ND	ND	1.9	ND	ND
13	7.2	4.9	2.8	6.8	3.0	4.5	Indan	ND	0.85	ND	0.41	ND	ND
14	8.7	5.5	6.2	11	3.3	5.2	1,2,3,4-Tetramethylbenzene	ND	ND	0.23	ND	ND	ND
15	7.0	7.3	11	24	4.3	5.6	Naphthalene	5.2	2.5	3.3	3.7	ND	ND
16	7.7	6.9	8.2	27	4.2	5.8	Benzothiophene	ND	ND	ND	ND	ND	ND
17	11	8.5	1.2	50	4.2	5.8	2-Methylnaphthalene	10	4.1	5.2	8.0	ND	ND
Pristane	41	0.29	150	49	8.4	10	1-Methylnaphthalene	6.9	3.2	3.4	6.0	ND	ND
18	7.2	8.8	7.2	50	5.1	5.9	Biphenyl	0.91	0.65	0.78	3.3	1.2	0.85
Phytane	6.6	6.0	3.4	31	3.7	3.9	2,6-Dimethylnaphthalene	5.2	2.2	3.1	5.6	2.0	1.6
19	12	13	11	56	6.4	7.0	2,3,5-Trimethylnaphthalene	3.2	1.6	ND	0.67	ND	ND
20	ND	9.3	10	34	5.6	6.7	Fluorene	1.1	0.75	1.2	1.8	ND	1.4
21	4.1	15	9.7	25	4.6	6.4	Dibenzothiophene	0.78	ND	0.45	ND	ND	ND
22	ND	23	10	16	6.0	6.6	Phenanthrene	10	6.0	5.4	8.4	3.6	4.9
23	ND	39	12	16	11	8.2	Anthracene	ND	ND	ND	ND	ND	ND
24	ND	46	12	9.3	12	6.7	1-Methylphenanthrene	0.89	ND	0.63	0.21	ND	ND
25	ND	73	21	7.3	14	9.7	Fluoranthene	8.7	2.9	5.9	ND	ND	4.5
26	ND	57	9.9	6.6	14	5.8	Pyrene	4.8	6.7	5.3	7.5	ND	4.5
27	ND	65	13	11	19	8.6	Benz(a)anthracene	ND	0.46	0.4	ND	ND	ND
28	ND	60	6.8	3.7	13	5.9	Chrysene	ND	3.1	2.1	ND	ND	ND
29	ND	57	13	6.4	14	9.3	Benzo(e)pyrene	ND	ND	5.6	ND	ND	ND
30	ND	39	9.9	ND	6.8	ND	Benzo(a)pyrene	ND	ND	ND	ND	ND	ND
31	ND	55	11	8.6	7.6	ND	Perylene	ND	ND	ND	ND	ND	ND

MUSSELS

n-Alkanes # carbons	Spring	Summer	Fall	Winter	Aromatic hydrocarbons	Spring	Summer	Fall	Winter
10	ND	24	ND	ND	o-Xylene	ND	29	ND	ND
11	ND	ND	ND	ND	Isopropylbenzene	ND	ND	ND	ND
12	ND	110	14	ND	n-Propylbenzene	ND	23	ND	ND
13	ND	32	6.7	ND	Indan	72	ND	ND	ND
14	ND	66	14	30	1,2,3,4-Tetramethylbenzene	ND	ND	ND	ND
15	91	230	170	220	Naphthalene	ND	43	39	38
16	17	70	47	59	Benzothiophene	ND	ND	ND	ND
17	39	88	60	180	2-Methylnaphthalene	ND	110	110	23
Pristane	78	27	1300	970	1-Methylnaphthalene	ND	ND	27	ND
18	ND	56	12	47	Biphenyl	ND	ND	ND	ND
Phytane	300	820	310	400	2,6-Dimethylnaphthalene	ND	ND	ND	ND
19	120	360	110	130	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND
20	71	140	97	87	Fluorene	ND	ND	ND	ND
21	63	150	59	100	Dibenzothiophene	19	19	ND	ND
22	17	220	120	120	Phenanthrene	85	120	130	37
23	ND	170	81	130	Anthracene	ND	ND	ND	ND
24	ND	180	48	78	1-Methylphenanthrene	ND	ND	21	ND
25	ND	190	59	71	Fluoranthene	36	230	ND	650
26	ND	110	23	ND	Pyrene	51	98	81	700
27	ND	160	8.0	56	Benz(a)anthracene	ND	49	ND	150
28	ND	320	6.1	ND	Chrysene	ND	150	ND	15
29	36	430	ND	210	Benzo(e)pyrene	ND	ND	ND	ND
30	ND	350	ND	ND	Benzo(a)pyrene	ND	ND	ND	ND
31	ND	470	ND	ND	Perylene	ND	ND	ND	ND